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Solar Halo

By DAVID W. HAMLIN*

At approximately 10:30 A.M., C.S.T., on April 3, 1936, a fairly complex solar halo was observed at Dearborn Observatory of Northwestern University, Evanston, Illinois, of which the following is a description.

The sky appeared to be very clear, except for low lying haze to the eastward over Lake Michigan and very low clouds on the western horizon. The sun was very bright and could be observed only with considerable discomfort even through deeply colored glass. The temperature was approximately 32° F.

The halo of 22° (*aa*) was distinct and well defined, being a complete circle, white except for two points, one directly above and the other directly below the sun, which were brilliant and highly colored. The point above the sun (*g*), at which the halo of 22° joined with a possible portion of a secondary parhelic circle (*dd*) of about the same diameter, was more brilliant and highly colored than the one below (*i*), where the halo of 22° seemed to merge with low-lying haze. A second halo, somewhat eccentric to the sun and joining with the halo of 22° (*ee*) at the northern side, extended outward around the halo of 22° and merged to the southward with the same apparent haze which had somewhat the appearance of radiation fog. These two circles were of about equal intensity.

The parhelic circle (*bb*), although well defined and unbroken, was slightly less intense than the halo of 22°.

The anthelion (*h*) was not of sufficient brightness to attract particular attention. There were, however, two wide angle oblique arcs (*cc*) through the anthelion which seemed to extend toward the sun and merge with the southern portion of the secondary parhelic circle. If the secondary parhelic circle was complete the observer failed to note it. This secondary circle (*dd*) and the oblique arcs (*cc*) were very much fainter and more tenuous than the parhelic circle (*bb*) and the two circles about the sun (*aa*) (*ee*), and were not observed during the first part of the display, though they may well have been visible and escaped notice due to the inexperience and lack of training of the observer.

To the eastward over Lake Michigan there appeared an arc of a rainbow (*j*), probably about 40 degrees in length. At its highest point in the sky it faded out into tenuous fog, and to the southward disappeared in dense, low-lying radiation fog. Particular notice was taken that no

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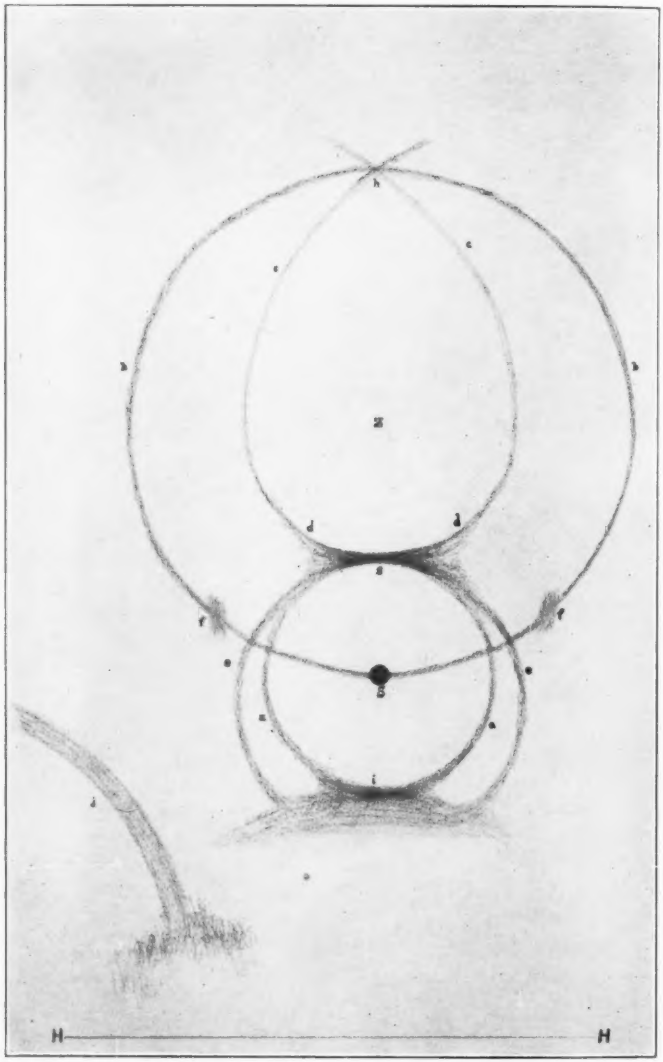


SOLAR HALO AS OBSERVED AT EVANSTON, ILLINOIS, APRIL 3, 1936.

corresponding arc appeared in the west. This "rainbow" arc, too, was observed later during the display.

The sun dogs (*ff*) were of no great brilliance, and were not highly

colored. If these were intersections of the halo of 46° (not otherwise observed) with the parhelic circle, they probably should appear to cross the parhelic circle at right angles. The observer hesitates, however, to change his impression obtained through actual observation of the phenomenon.

The whole phenomenon disappeared within a fairly short time, being practically invisible, excepting for the parhelic circle, within an hour after it was first noted by the observer. Toward the last the parhelic circle seemed to break up into a cirro-cumulus cloud effect, the sky appearing clear inside and outside the circle, but showing the mackerel effect in the band of the circle itself, and giving the impression of being extremely high and distant in the sky.

Mr. Howard Campaign, graduate student in Mathematics at Northwestern, rendered valuable aid in the actual observation and in making the rough drawing of the phenomenon.

Grateful acknowledgment is made for the advice and guidance given by Dr. Oliver J. Lee, Director of Dearborn Observatory, in preparing this material.

All identifications of features of the display were obtained from *Physics of the Air,* and identifications of fog and cloud types from *Fogs and Clouds,* both by W. J. Humphreys.

Elijah Hinsdale Burritt
The Forgotten Astronomer

By ALBERT J. BROOKS

The author of "Geography of the Heavens" can truly be called the "forgotten" astronomer, for the usual sources of information reveal nothing at all concerning Burritt's life. Indeed in all the encyclopedias and biographical dictionaries consulted, his name did not even appear. And yet his book, selling for more than a generation, must have played a great part in spreading a knowledge of astronomy among the people of the United States.

Professor Sherburne W. Burnham, the foremost double-star astronomer in this country, was first drawn to the study of astronomy by the purchase of a copy of "Geography of the Heavens" in 1862 at an auction sale in New Orleans. It is more than likely that there are many astronomers today who have a copy of this work tucked away on their book shelves, and they would not willingly part with it. Surely an astronomer who made such a contribution to the literature of the science deserves to be known to all students of astronomy. It seemed, therefore, worth while to attempt to find out what could be learned about Burritt's life, even after the long lapse of time since his death in 1838. The following has been gathered after much searching through books

and other publications, and by correspondence. And the writer desires at this point to express his thanks to the many persons with whom he has been in correspondence for their kindly help in giving information that could not otherwise have been obtained.

Burritt's Life

The first of the Burritt family on record is William Burritt, who is supposed to have come from Glamorganshire, Wales, and who settled in Stratford, Connecticut. He died there in 1651. It is believed that William Burritt is the ancestor of all the Burritt families in the United States.

The family seems to have lived in the same town for many generations, as Elijah Burritt's father, Elihu, was born in Stratford, December 13, 1765. He was a farmer and a shoemaker, working on the farm in the summer and at shoemaking in winter. It was not uncommon at that time for farmers to carry on another occupation during the winter months. At sixteen years of age he, with his father, also named Elihu, enlisted in the Revolutionary Army and served until the end of the war.

Elihu Burritt moved to New Britain in early life and there carried on the occupations mentioned. On July 20, 1793, he married Elizabeth Hinsdale, a daughter of Elijah Hinsdale, after whom the astronomer was named. They had a family of ten children, Elijah H. being the eldest.

Although having their own home which came to them from the mother's family, it was a great struggle to bring up ten children. The failure of a flour mill the father owned made them poor, and the children grew up under circumstances verging on poverty. But the parents were persons of courage and high ideals, and brought up their children to be ambitious. It is therefore not surprising that at least two of the children became well known.

The youngest son, though not the youngest child, was also named Elihu Burritt. He became famous as a linguist, and was said to be able to read and speak fifty languages and dialects. Elihu spent a great part of his life as a leader in the movement for international peace, and was as well known in Europe as he was in this country in furthering that cause. In 1848 he was elected vice-president of the Peace Congress then assembled at Brussels. In view of world conditions today it would appear that Elihu Burritt was very much in advance of his time. He lectured extensively and wrote many books. As he learned the blacksmith's trade in his youth, he was often called "The Learned Blacksmith."

It is perhaps of interest to note in passing that a cousin of the Burritt family was Emma Hart Willard, a pioneer educator of women, who in 1821 founded and directed for many years the Troy Female Seminary. She published many historical books, and a volume of poems which included the words of the once popular song "Rocked in the Cradle of

the Deep." A tablet to her memory is in the Hall of Fame, New York City. Her sister was Almira Hart Phelps, also an educator, who wrote many school text books as well as works on botany, chemistry, geology, and natural philosophy.

Elijah Hinsdale Burritt, the astronomer, was born on April 20, 1794, in New Britain, Connecticut. Little is known of his early life, but he probably received the usual public school education of the time, and, since he was the eldest child, it is likely that some of the burden of the family fell upon him.

When a young man of perhaps eighteen years of age Elijah was sent to Simsbury, Connecticut, to learn the trade of blacksmith from Samuel Booth. He remained there for about two years, and during that time took up the study of astronomy and mathematics.

Shortly after returning to New Britain Elijah met with an accident which crippled him for several months, and necessitated his walking with crutches. He used his enforced idleness in continuing his studies of mathematics and other subjects. His studiousness attracted the attention of his friends, and as soon as he could dispense with his crutches they interested themselves in sending him to Williams College. He entered the college in 1816, as a member of the class of 1819. In 1817, in order to raise funds for continuing his studies in college, he became a teacher in Sanderson Academy, Ashfield, Massachusetts. One of his pupils was Mary Lyon, who in 1837 founded Mount Holyoke College. Burritt returned to Williams College in 1818, but left before the time for graduation.

In 1819 Burritt went to Georgia, locating in Milledgeville, which was at that time the capital of the state. He taught school there for a time, did some civil engineering work, and was editor and proprietor of a weekly newspaper for several years. He married Ann W. Watson, of Milledgeville, Georgia, on October 28, 1819. They had five children. While in Georgia Burritt was employed by the state in making a survey of the Chattahoochie River, which forms part of the boundary between Georgia and Alabama. In the state archives at Atlanta there is a forty-eight page manuscript report of this work. It bears the date 1826.

Although a northerner, Burritt did not in his newspaper advance any anti-slavery views. In the north, however, agitation of the slavery question was active. Abolition societies were formed, and pamphlets against slavery were published. Some of these pamphlets were sent to Burritt by well-meaning friends, and instead of taking care of them he let them lie around in his office where they were picked up and read. Quite naturally, they aroused suspicion as to his views on the subject. Finally the feeling against Burritt became so violent that he was compelled in 1829 to leave everything and go north to New Britain. All his property, the accumulation of years of hard work, was confiscated.

Back in New Britain, Burritt had to begin life anew. He owned some property known as the "Stone store." He remodeled the building for

a school, turned the upper floor into an observatory, purchased a telescope and other apparatus, and opened a Boarding and Day School, where "instruction was given in the higher English studies and in the ancient and modern languages." His brother Elihu, who was seventeen years younger than Elijah, attended this school for a time, and assisted also in teaching. This school Burritt carried on for several years.

In 1837 Burritt organized and headed a party of colonists to go to Houston, Texas, with the expectation of making a permanent home there. Texas had seceded from Mexico in 1836 and set up an independent republic. Laws were passed making liberal grants of land to colonists. Burritt's party numbered thirty persons, and included his sister, Emily, and his brother, William. Emily Burritt kept a journal of the trip, and it is from this journal that the events of the journey are learned.

The enterprise was unfortunate and resulted in disaster. A ship was chartered to take the party to Galveston. The voyage took twenty-eight days, and upon arriving at Galveston they were met by a storm that brought shipwreck. The vessel was driven upon a sand bar, the masts and rigging had to be cut away to prevent foundering, and it was several days before the party was able to land. In a few more days they reached Houston, only to find that no adequate preparation had been made for them. They were forced to live in tents. Yellow fever broke out before many days and resulted in the death of most of the colony. Elijah Burritt and his brother, William, were among the victims. Elijah's death occurred January 3, 1838, just a few weeks after the party arrived at their destination.

At the time of his death Burritt was not quite forty-four years of age. His passing was a distinct loss to astronomy, for had he lived the ordinary span of man's life, he would undoubtedly have greatly enriched the literature of astronomy by the publication of more books on the subject.

Alfred Andrews in his "History of the First Church in New Britain" thus describes Burritt: "He was a well-built large man, of commanding appearance and dignified address, of more than ordinary talents. He became a distinguished mathematician and astronomer."

Burritt was an intensely religious man, as a perusal of his "Geography of the Heavens" will show. He joined the Congregational Church of Simsbury on July 1, 1814. Later, in 1833, he and his wife joined the First Church in New Britain. On December 7, 1835, he was elected Moderator of the New Britain Ecclesiastical Society. When Burritt went to Williams College his mother and his friends hoped that his education would lead him to become a clergyman, but apparently astronomy and teaching made a greater appeal.

Burritt's Writings

When we come to consider Burritt as an astronomer and as a writer of text books we realize his unusual ability. He had a thorough knowledge of the astronomy of that period, and also had the gift of writing in such a simple, interesting and attractive way as to hold the attention of the reader. Consequently his books became popular and were used in many schools and colleges.

Even while Burritt was a student at Williams College, he published his first book, called "Logarithmick Arithmetick." The preface is dated "Williams College, October, 1818," and it was copyrighted September 15, 1818.

It is a book of 252 pages. The first part consists of a text book on arithmetic, occupying a little more than half the book. This is followed by a section on astronomy, including many astronomical tables. It explains the motions of the earth and the moon around the sun, describes an easy method of calculating solar and lunar eclipses, and is illustrated by a projection of the eclipses. This is followed by forty pages of tables of logarithms from 1 to 10,000, extended to seven places, and describing a method for carrying the logarithms up to 10,000,000. The whole work is carried out in a very thorough manner. It was surely an ambitious work for a college student of twenty-four years of age, and gives much promise for his future.

The next known work of Burritt's is a twenty-eight page pamphlet that he published while he was in Georgia. It is called "Astronomia, or directions for the ready finding of all the principal stars in the heavens which are named on Carey's Celestial Globe. Designed for the amusement and instruction of young ladies and gentlemen who are without the usual means of globes, charts, etc." It was printed at the Georgia Advertiser office, in Augusta, Georgia, 1821.

After Burritt returned north to New Britain, he published in 1830 a thirty-two page pamphlet called "Universal Multipliers for computing interest, simple and compound; adapted to the various rates in the United States, to which are added tables of annuities and exchange." This was published in Hartford, Connecticut.

Burritt's most important work, and the one by which he is generally known, is his "Geography of the Heavens," with its accompanying "Celestial Atlas." He at first intended to call it "Uranography," but he yielded to his publisher's wishes, and it was issued as "Geography of the Heavens." In his preface Burritt stated that he wanted the book to be to the heavens what geography is to the earth.

The Geography begins with descriptions of the constellations, and Burritt goes deeply into the mythology, poetry, and history of each one. He also points out many individual stars, giving their names, magnitudes, and other interesting facts about them. With the aid of the Atlas, the student or reader can easily identify the constellations, and thus become familiar with the stars.

This section is followed by one on the solar system. This, of course, covers all the known planets, satellites, comets, and the laws governing their motions; also eclipses, transits, etc. Following this are a number of problems for the student to solve, and finally thirteen astronomical tables are given. There are many illustrations in the section on the solar system. At the foot of each page there are questions for the student which relate to the information on that page, as was the custom of the time.

In the "Celestial Atlas," which accompanied the Geography, Burritt depicted the constellations in a graphic manner. In addition to showing the stars to the sixth magnitude, he outlined the figures of the birds, animals, etc., that gave the constellations their names. These figures were shown in contrasting light colors, and gave the whole Atlas an appearance that was attractive and vivid. There were seven maps, each 14 inches by 13 inches; one of the north polar region, one of the south polar region, and four of the equatorial region. The last map was of the entire heavens on the Mercator projection, and showed the sun's place in the ecliptic for every day in the year. These maps were all drawn by Burritt and engraved under his supervision. The complete work was planned primarily for use in schools and colleges, and was probably the best exposition of the subject of astronomy that had appeared in this country up to that time.

These two—the Geography and the Atlas—were published early in 1833, in Hartford, Connecticut. It would appear that the country was ready for just such a work, for the entire edition was sold in a year, and a second edition was issued in 1835. This also was soon exhausted, and preparation was made for a third edition, which was issued in 1836. For this edition an introduction was written by Dr. Thomas Dick, the eminent Scottish writer of scientific and philosophical works. The title of his introduction was "Advantages of the Study of Astronomy." Professor Olmsted, of Yale College, also contributed a short article on Meteoric Showers. Both of these writers voiced their appreciation of Burritt's work. Much new matter was added, and the work was stereotyped so that further editions could more easily be printed.

The Atlas was also improved by adding another page illustrating the solar system. This showed the relative sizes of the sun, moon, and planets, their relative distances, the inclinations of their orbits, and many other facts concerning the solar system. The entire Atlas was reengraved on steel.

It is not known how large the editions were, but it is safe to assume that the popularity of the work caused larger editions to be printed. The third edition was sold in a few years, and a fourth was published in 1841. In the meantime Burritt had died, and there was no change in either the Geography or the Atlas. The years 1844, 1846, and 1849 saw new editions issued.

In 1852, the Reverend Hiram Mattison* revised the Geography, which was issued in that year. In all editions, including that of 1852, the Geography was of the size known as 18mo, the pages being 6½ inches by 4 inches. For the next edition, in 1856, Mr. Mattison again revised the Geography, adding new material, and more illustrations, and it was issued as 12mo, the pages being 7¼ inches by 4¾ inches. Mr. Mattison also added to the Atlas two pages containing eighty drawings of double stars, clusters, comets, and nebulae. On the back cover was a large cut of the new 15-inch telescope of the Harvard Observatory. The publication office was brought to New York, and the work was re-copyrighted in 1856. All subsequent editions bore on the outside cover the title "Burritt's Geography of the Heavens." The work was thus brought up to date, and made still more valuable as a text book.

The country evidently was still far from being supplied with sufficient copies of this work, for new editions were issued in 1858, 1859, 1863, 1866, 1868, 1873, and 1876. Whether any other editions were issued is not known, but the writer has personally checked up on all those mentioned. These total sixteen editions, and the preface of the last one states that over 300,000 copies had already been sold.

A work selling for a period of forty-three years (1833 to 1876) in sixteen editions, and totalling over 300,000 copies, is certainly unique in the annals of astronomy. Such an achievement should place Burritt among the great teachers of astronomy in America

BROOKLYN, NEW YORK, JANUARY, 1936.

*Reverend Hiram Mattison was a Methodist clergyman, who held pastorates in and around New York City. He was Professor of Natural Philosophy in the Falley Seminary, and was the author of Primary Astronomy, Elements of Astronomy, and High School Astronomy. He was born on February 11, 1811, and died in Jersey City, New Jersey, November 24, 1868.

Who First Explained the Nova Bands?

By DEAN B. McLAUGHLIN

The explanations offered for the structures of the bands in the spectra of novae have been numerous. They have included anomalous dispersion, pressure shift, and the collision of a bright-line star with a dark-line star (the bright-line star always receding and the dark-line one always approaching!). Observations of spectra of novae during the present century have shown these hypotheses to be untenable. The explanation now generally accepted involves the ejection of a shell of gas from the star. This expands rapidly in all directions; the receding gas on the far side of the star gives bright lines shifted to the red by Doppler effect, that which moves to the side, across the line of sight, gives undisplaced emission, and that which lies immediately between the star and the observer gives absorption lines shifted to the violet by

its rapid velocity of approach. No valid bit of evidence against this hypothesis is now known to exist; the gaseous shell itself has been seen expanding around several novae, and recently the spectrum of the nebula around Nova Persei has shown Doppler shifts which confirm this interpretation.

Now that the correct explanation has been established, it is of interest to inquire as to its author. In various places the writer has seen it credited to three different astronomers. If the credit for an hypothesis truly belongs to the first scientist who stated it clearly, all three of the alleged authors followed some years in the wake of the first who made the suggestion. In *Astronomy and Astrophysics*, **13**, 202, 1894, W. H. Pickering writes as follows: "After many centuries of quiescence and contraction a series of eruptive prominences upon an enormous scale burst forth, spreading in every direction and completely enveloping the star upon all sides. When they first appear they present a spctrum of bright lines, but in a few hours the gases first emitted have receded to a considerable distance from the star, and have cooled down owing to the rapid expansion involved by their recession, . . . This cold advancing atmosphere produces a series of dark absorption lines. It at the same time cuts off the light from the hot advancing prominences behind it, . . . The hot receding prominences, however, extending away for perhaps millions of miles behind the limb of the star, give out light whose wave-length cannot be absorbed by the cold advancing atmosphere. They therefore shine with their full brilliancy."

With due allowance for the primitive state of knowledge of the physics of stellar atmospheres forty-two years ago, the foregoing quotation is in its broad features, the "expanding shell hypothesis" now generally accepted. Whether one thinks of a great number of prominences coalescing and enveloping the star, or of a star blowing off its entire atmosphere, the structure of the bands would be quite similar. Apparently, therefore, the credit for first formulating this explanaion belongs to W. H. Pickering. The most curious feature of this question of priority is the fact that those generally given credit published in only one place, while Pickering repeated the above explanation in two later papers,* each time referring to the original paper.

This is but one of a number of cases which show that each generation of scientists has to learn, by hard experience and duplication of previous researches, the facts and laws which were established long ago but have become buried in the literature. But perhaps it is better so, since our present publications will be dust in a few centuries.

Astrophysical Journal*, **13, 277, 1901; POPULAR ASTRONOMY, **26**, 605, 1918.

The Simpler Aspects of Celestial Mechanics

By HOMER A. HARVEY

(Third Paper)*

The Ecliptic

Let us suppose, in order to set up what we may call standard conditions, that the axis of the earth is perpendicular to the plane of its orbit, and let us inquire what would follow from that supposition. The earth's equator would lie in the orbital plane, and hence the celestial equator would always pass through the sun. Similarly, the planets and the moon, since their orbits all lie near the plane of the earth's orbit, would always be found on or near the celestial equator. The sun would always rise due east and set due west, and day and night would be equal for all parts of the earth except the regions very near the poles, which would enjoy perpetual day. For any given latitude the climate would be invariable, with the same season continuously.

Fortunately for us, at least in the matter of variety, the inclination of the axis to the plane of the orbit of about $23\frac{1}{2}°$ and its constant absolute direction in space change the whole aspect of physical conditions upon the earth and, incidentally, furnish the amateur astronomer with his greatest *bête noire,* the ecliptic.

If we choose a date upon which the north half of the earth's axis is tipped as far away from the sun as possible, it will be apparent that the earth's equatorial plane projected into space will pass to the *north* of the sun; in other words, the sun will appear in the sky *below* the celestial equator. Now, upon a date approximately six months later, when the earth will have reached a point in its orbit opposite its first position, the axis having meantime maintained its original direction in space, it is equally clear that the equatorial plane will pass *south* of the sun, and that the sun will appear *above* the celestial equator. Furthermore, its angular distance above the equator will be equal to its former distance below it. Upon a little reflection it will be obvious that these conditions will obtain for any pair of opposite points upon the orbit. Consequently, as the sun moves eastward among the stars day by day, an optical illusion created by the earth's continuous eastward progress in its orbit, it will apparently follow a path with definite characteristics: (1) it will have a reciprocal positive and negative symmetry with respect to the celestial equator, and its halves will be symmetrical to two hour-circles, those at the 6-hour and 18-hour right ascension points. (2) it will cut the celestial equator in two points, and (3) it will reach a maximum distance from it of $23\frac{1}{2}°$, plus and minus.

*For preceding papers, see February and April (1936) issues of Popular Astronomy.

With these data in hand, we may now proceed to plot the ecliptic. Since it is convenient and customary to make axes of reference straight lines, we may therefore confer this honor upon the celestial equator, and accordingly take a strip from the celestial sphere something more than 47° wide, say 25° on either side of the celestial equator, cut it through at some point, preferably at one of the intersections with the ecliptic, and flatten it out into the plane of the drawing. The celestial equator will now appear as a straight line, with the ecliptic a curve, resembling the sine curve, laid upon it.

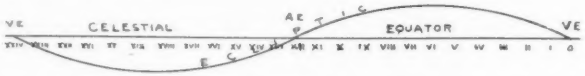


FIGURE 1
V.E. = Vernal Equinox, A.E. = Autumnal Equinox.

If we have cut this band at the *vernal equinox,* the upward, plus swing of the curve will appear to the left, or eastward, of it, and, since we have already agreed to begin our right ascension figures at this point, we may put them in as shown in the drawing. At 12^h R.A. will be the *autumnal equinox,* and following this the minus swing of the curve, ending at the vernal equinox again at the left extremity of the drawing.

It will be seen that if we roll up the drawing into its original position in the celestial sphere before being cut and flattened out, the two points labelled "vernal equinox" fall upon each other and become identical, and that the two lines, the celestial equator and ecliptic, are in reality two great circles of the celestial sphere. The apparent sinuous character of the ecliptic is merely the result of our projection of the band upon a flat surface. Had we chosen as our plane of reference the ecliptic instead of the celestial equator, the situation would have been reversed—the equator would then have appeared as a sinuous curve upon the straight line of the ecliptic.

We have chosen to develop in detail the genesis of the map in order to show that there is nothing inevitable about the appearance of it as traditionally shown. What it really represents is not the actual appearance of the situation, an ideal, as has already been pointed out, which is well-nigh impossible when dealing with astronomical figures, but the mathematical relationships. That it does do this we may now proceed to show.

If the assumptions of Figure 1 be correct, it is apparent that for any given right ascension there must be a corresponding declination, and only one. On the other hand, for any numerical value of the declination, positive or negative, there must be *two* values of the right ascension. Naturally, for values of the right ascension of 0 or 12^h, since the ecliptic crosses the equator at these points, the values of the declination will be zero.

We may now develop the formula connecting the right ascension and

declination for points on the ecliptic. This is based upon the fundamental problem of the behavior of a radius swept around in one of two intersecting planes, about some point in their intersection as a center, and a study of the value of the vertical angle between this radius and the other plane corresponding to any given position of the radius in its excursion. This will be made clear by Figure 2.

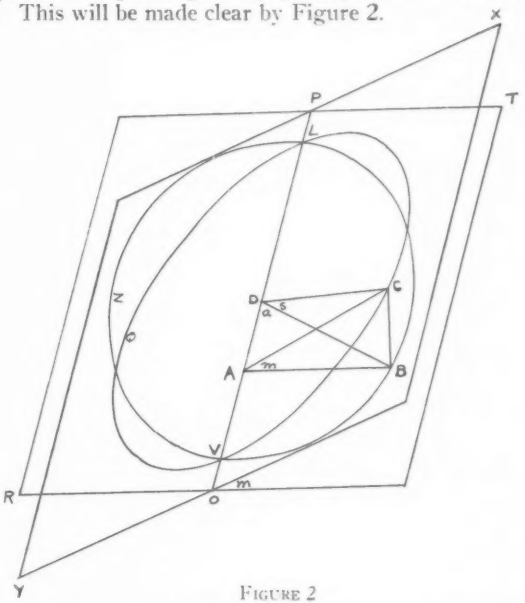


FIGURE 2

Let YX and RT be two planes, intersecting at the angle m, and in the line of intersection OP.

Let D be a point in the line of intersection, and DB be a radius revolving about D as a center, and lying in the plane RT.

Erect BC perpendicular to plane RT, and meeting plane YX in C and draw DC.

From B drop a perpendicular BA to OP, meeting it in the point A and draw AC.

Then angle CAB is equal to angle m by geometrical definition.

Angle a is the amount of rotation of DB from its initial position DO.

Angle s is the vertical angle between DB and the plane YX.

Problem: to establish the relationship between angles a, s, and m.

$$\text{Sin } a = \text{AB/DB}, \quad \text{whence AB} = \text{DB} \times \sin a.$$

$$\text{Tan } m = \text{CB/AB}.$$

Substituting in this the above value of AB, we obtain

$$\text{Tan } m = \text{CB}/(\text{DB} \times \sin a) \qquad (1)$$

$$\text{Tan } s = \text{CB/DB} \qquad (2)$$

From (1), $\text{CB} = \tan m \times \text{DB} \times \sin a$

From (2), $\text{CB} = \tan s \times \text{DB}$

Equating, $\text{DB} \sin a \tan m = \text{DB} \tan s$.

Dividing by DB, $\tan s = \tan m \sin a$.

If, now, we imagine ouselves at D, the center of the earth, looking out along the plane RT, the equatorial plane, to the celestial equator, VBLZ, and along the plane YX, the plane of the earth's orbit, to the ecliptic, VCLQ, the analogies will be at once apparent.

Angle *a* is the angular distance of B from V, the vernal equinox, and is hence the right ascension of B.

Angle *s* is the vertical angular distance from C to the equator, and is hence the declination of C.

Angle *m* is the angle between the planes of the equator and the orbit, and for the year 1936 is equal to 23° 26′ 50″.

$$[m = 23° 27′ 8.″26 - 0.″4684\ (1936 - 1900)]\ (\textit{American Ephemeris})$$
$$\text{Tan } 23° 26′ 50″ = .43373.$$

The formula therefore becomes

Tan declination = Sin right ascension × .43373.

which is the formula relating to points upon the ecliptic.

Example 1. What is the declination of a point on the ecliptic whose R. A. is $21^h\ 18^m\ 30^s$?

Solution: Reducing R.A. to degrees, $(1^h = 360° \div 24 = 15°)$

$$21^h\ 18^m\ 30^s = 319°\ 37′$$

$$\tan \text{decl.} = \sin 319°\ 37′ \times .43373 = \sin (270° + 49°\ 37′) \times .43373$$
$$= -\cos 49°\ 37′ \times .43373 = -.64790 \times .43373 = -.2809$$
$$\therefore \text{decl.} = -15°\ 41′\ 20″. \quad \text{Ans.}$$

Example 2. The R.A. of the sun is $6^h\ 32^m\ 44^s$. What is its declination?

Solution: $$\text{Tan decl.} = \sin 98°\ 11′ \times .43373 = \sin (90° + 8°\ 11′) \times .43373$$
$$= \cos 8°\ 11′ \times .43373 = .98982 \times .43373 = .429$$
$$\therefore \text{decl.} = +23°\ 14′. \quad \text{Ans.}$$

(The quantity .429 also represents the tangent of 203° 14′, but this angle has no meaning here, since the declination cannot exceed 23° 26′ 50″.)

Example 3. The declination of the sun is 11° 32′ 53″. What is its R.A.?

Solution:
$$\text{Tan } 11°\ 32′\ 53″ = \sin \text{R.A.} \times .43373$$
$$.20432 = \sin \text{R.A.} \times .43373$$
$$\sin \text{R.A.} = .20432/.43373 = .47125$$
$$\therefore \text{R.A.} = 28°\ 7′ \text{ or } 151°\ 53′\ (180° - 28°\ 7′)$$
$$\text{Reducing to hours, R.A.} = 1^h\ 52^m\ 24^s \text{ or } 10^h\ 7^m\ 30^s. \quad \text{Ans.}$$

Example 4. The R.A. of the sun is 12^h. What is the corresponding declination?

Solution: $$\text{Tan decl.} = \sin 180° \times .43373 = 0 \times .43373 = 0.$$
$$\therefore \text{decl.} = 0. \quad \text{Ans.} \quad (\text{coördinates of Autumnal Equinox}).$$

Example 5. The declination of the sun is −20° 17′. What is its R.A.?

Solution:
$$\text{Tan } -20°\ 17′ = \sin \text{R.A.} \times .43373$$
$$-.36958 = \sin \text{R.A.} \times .43373$$
$$\text{Sin R.A.} = -.36958/.43373 = -.8523$$
$$\therefore \text{R.A.} = -58°\ 28′ \text{ or } -121°\ 32′.$$
$$\text{Reducing to hours, R.A.} = -3^h\ 53^m\ 52^s \text{ or } -8^h\ 6^m\ 7^s.$$

Since R.A. cannot be negative, we must interpret this as reckoned *backward* (westward) from the vernal equinox. Choosing the one shown at the left of Fig. 1 (R.A. = 24^h) in order to make the subtraction, we have

$$\text{R.A.} = 20^h\ 6^m\ 8^s \text{ or } 15^h\ 53^m\ 53^s. \quad \text{Ans.}$$

Example 6. The decl. of the sun is 23° 26′ 50″. What is its R.A.?

Solution: Tan 23° 26′ 50″ = sin R.A. × .43373

.43373 = sin R.A. × .43373

sin R.A. = .43373/.43373 = 1

∴ R.A. = 90°

Reducing to hours, R.A. = 6^h. Ans.

Similarly, if the declination given above is negative in sign, the R.A. will be found to be —90°, and will therefore be $24^h - 6^h = 18^h$.

These are the coördinates of the *summer* and *winter* solstices, respectively.

That intersection of the ecliptic and celestial equator which lies at the beginning of the plus half of the ecliptic curve is called the *Vernal Equinox*, R.A. 0, Decl. 0, and, as has already been stated, has been chosen as the point from which R.A. is measured. 12^h farther eastward is the second intersection, the *Autumnal Equinox*, R.A. 12^h, Decl. 0.

It must be remembered that the ecliptic is the path of the sun's center, and only approximately the locus of the positions of the other bodies of the solar system. Therefore the formula given above may be used for calculating the unknown coördinate of the sun's position only. It will be further remembered that the sun progresses eastward along the ecliptic at the rate of about 4 minutes daily ($24^h \div 365\frac{1}{4} = 3^m\ 56^s$), that is, it shows this average daily increase in R.A.; that its diurnal course is very nearly parallel to the celestial equator, and lastly, that it is at the vernal equinox on or about March 21 of each year.

With these facts in mind, together with our knowledge of the relation of the celestial equator to the zenith for any given latitude, we are in a position to picture for ourselves with fair accuracy, and without the use of the *Ephemeris*, the course of the sun for any latitude and any day of the year.

Example 1. What is the course of the sun at Northampton, Massachusetts, on Otober 21?

Solution: Latitude Northampton = 42° 19′ N.

Day of year corresponding to March 21 = 80 (*Ephemeris*)

Day of year corresponding to October 21 = 294 (*Ephemeris*)

Days elapsed from March 21 to October 21 = 214.

$214 \times 4^m = 856^m = 14^h\ 16^m$, R.A. sun on October 21.

Tan decl. = $\sin 14^h\ 16^m \times .43373 = \sin 214° \times .43373 = \sin (180°+34°) \times .43373$

$= -\sin 34° \times .43373 = -.55919 \times .43373 = -.2425$

∴ decl. = —13° 38′

The celestial equator at Northampton is tipped 42° 19′ from the zenith. Therefore on October 21 at that place the sun will cross the meridian

42° 19′ + 13° 38′ = 55° 57′, south of the zenith,

and will follow a course parallel to the celestial equator.

Example 2. On what days of the year will the sun cross the meridian 48° 40′ south of the zenith at Oakland, California?

Solution: Latitude Oakland = 37° 47′ N.

48° 40′ — 37° 47′ = 11° 3′, distance of sun south of celestial equator.

tan — (11° 3′) = sin R.A. × .43373

— .19529 = sin R.A. × .43373

sin R.A. = — .19529/.43373 = — .4505

R.A. = 26° 47′, or —153° 13′.

Reducing to hours and subtracting from 24,

R.A. = $22^h\ 13^m$ or $13^h\ 47^m$.

These values correspond, at the rate of 4^m gain a day, a value about 2% too large, to 333 and 207 days after March 21, that is, to the 413th and the 287th days of the year. These are February 17 and October 14. Ans.

The actual dates are February 20 and October 22, by reference to the *Ephemeris* for the dates corresponding to the above R.A. figures. The error is large in this instance, because the dates happen to fall at a time of year when the declination is changing rapidly, and when the *Equation of Time* is large, that is, when the real sun is far out of its average position, a discrepancy which will be discussed later. However, the result is fairly close for rapid calculation and illustrates the principle admirably.

Example 3. On board ship on June 10. The sun is observed to pass through the zenith. What is the latitude?

Solution: Day of year corresponding to March 21 = 80
Day of year corresponding to June 10 = 161
Days elapsed from March 21 to June 10 = 81
$81 \times 4^m = 324^m = 5^h\ 24^m$, R.A. sun on June 10.

$$\tan \text{decl.} = \sin 5^h\ 24^m \times .43373 = \sin 81^\circ \times .43373 = .98769 \times .43373 = .4283$$

$$\therefore \text{decl.} = 23^\circ\ 11'.$$

Therefore the celestial equator must be 23° 11′ south of the zenith, and the latitude is North 23° 11′. Ans.

It is assumed that by this time the amateur has obtained a copy of the *Ephemeris and Nautical Almanac* for 1936. He will do well to familiarize himself, by practice, with the use of the coördinates of familiar celestial objects, and he will soon become adept in the mental calculations necessary to locate, with considerable accuracy, the object in question, and, more important still, will presently become "celestial sphere conscious," a state of mind as important to the budding astronomer as position sense is to the aviator. In the process of establishing his celestial framework, the amateur's first thought will soon automatically be directed toward locating the celestial equator and the vernal equinox. The equator will cause him no difficulty, since he knows the position of both ends of the visible half, and he has become accustomed to fixing, in accordance with his latitude, the point where it crosses his meridian. The location of the vernal equinox for a given moment, however, will not be so obvious.

First let the student remember that the sun and the vernal equinox are together on the meridian at noon on March 21, and that the vernal equinox moves westward, relative to the sun, at the rate of about 4 minutes (1°) daily. To locate the vernal equinox for any moment on any given date, therefore, he will have two motions to take into account: (1) the *hours* elapsed since noon, and (2) the *days* elapsed since March 21. The westward motion of the vernal equinox due to the sum of these two quantities will give its position relative to the meridian at the moment. The application of this principle may now be illustrated.

In the ephemeris of the sun given in the *Ephemeris and Nautical Almanac*, the student will find the days of the year serially numbered, with March 21 as No. 80. For any other date, a simple subtraction will indicate the number of days elapsed since that time. This number multiplied by 4 will give him approximately the westward advance of the vernal equinox in minutes of time since March 21, as compared with the

sun. This amount, *added to the time since noon*, and then changed to degrees, will fix at once the position of the vernal equinox west of the meridian. The application now of the coördinates of any celestial body becomes a simple matter, remembering that the east and west points of the horizon are separated by 12^h of R.A., and that the meridian is 6^h from each. The fact that the diameter of the sun or moon is about $\frac{1}{2}°$ will furnish him a convenient standard for smaller angular measurements.

A single example will suffice to make clear the procedure described above:

Example. Locate the vernal equinox on May 5, at 3:00 P.M.

Solution:

Serial No. March 21	80
Serial No. May 5	125
Days elapsed	45

$45 \times 4^m = 180^m = 3^h$ (first quantity)

Hours elapsed since noon $= 3^h$ (second quantity)

Adding, we have 6 hours, total motion of vernal equinox westward, relative to meridian.

Therefore, the vernal equinox is 6^h west of the meridian and on the celestial equator, that is, at the west point of the horizon. Ans.

Bear in mind that the vernal equinox is always on the celestial equator, whereas the sun may be anywhere from $23\frac{1}{2}°$ north of it to an equal distance south, and that proper allowance must be made for the existing status in our mental calculations.

In order to locate, at the moment indicated above, an object whose coördinates are, say, R.A. 7^h, Decl. $-20°$, we would begin at the vernal equinox on the horizon, run eastward along the celestial equator to 1^h east of the meridian, thence southward along the corresponding hour-circle to a point $20°$ from the equator, where the object would be found.

It is apparent that if we had a clock so regulated as to gain $3^m\ 55^s.5$ a day over a mean solar time clock, it would keep pace with the *stars*. If then we should set it to show 0^h at noon on March 21, it would constitute a simple and direct means of locating the vernal equinox, since sidereal time (the time shown on such a clock) may be defined as "the hour angle (distance in hours west of the meridian) of the vernal equinox." Any good clock can be regulated to gain the proper amount; all the more convenient if by a simple reducing train of gears its hour-hand be made to show readings from 0 to 24, so as to correspond to the R.A. figures. It will then also have the additional advantage that its hour-hand will always indicate the hour angle of the vernal equinox. The amateur can thus have a serviceable sidereal clock of his own. He will find it an indispensable part of the equipment he may hope eventually to possess.

Time may appropriately be made the subject of the next paper.

Figure 3 has been added as a résumé of the ground thus far covered. A careful study of the figure and legend will make clear many of the points already discussed.

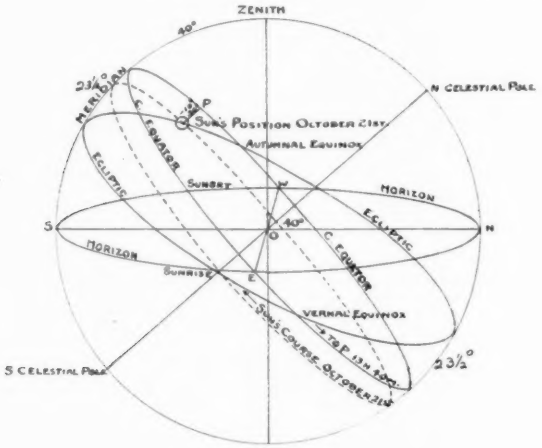


FIGURE 3.

OBSERVER AT O. LATITUDE, 40° N, TIME, OCTOBER 21, ABOUT 3:00 P.M.

Note (1) Elevation of Pole, 40°. (2) Depression of Celestial Equator from Zenith, 40°. (3) Equator passes through E and W points. (4) Ecliptic is inclined to Equator 23½°, and like it is a Great Circle of the Celestial Sphere. (5) The Vernal and Autumnal Equinoxes are the two points of intersection of the Ecliptic and Equator, and are opposite each other upon the Celestial Ephere, 12 hours apart. (6) The sun has advanced one month in the Ecliptic from its position on September 21, the Autumnal Equinox, R.A. 12^h, Decl. 0°, to its present position, R.A. 13^h 40′, Decl. —10° 30′. (7) The course of the sun for that day, as for any day of the year, is a small circle of the Celestial Sphere, and parallel to the Equator. (8) The sun is south of the Equator, hence less than half its daily path is above the horizon, and the day is shorter than the night. (9) The sun rises south of E and sets south of W. (10) The time of *year* may be estimated from the sun's position in the *Ecliptic;* the time of *day* from its relation to the *Meridian.* (11) The Celestial framework, consisting of Equator, Ecliptic, and both Equinoxes, glide over the local framework, consisting of Horizon, Meridian, and Zenith, and makes a complete rotation daily.

BATAVIA, NEW YORK.

The Variability of Epsilon Lyrae

By E. A. FATH

In 1931 the stars ϵ^1 and ϵ^2 Lyrae were found to be variable[1] from observations made with a photo-electric photometer attached to the 12-inch refractor of the Lick Observatory. The mean period of ϵ^1 was approximately $0^d.2$ on the basis of observations on five nights and the mean period of ϵ^2 was about $0^d.06$ from observations on seven nights. The range of the mean curves was approximately $0^M.02$ for each star. The brighter component of ζ Lyrae was used as a comparison star for both the 1931 and later observations. It is to be understood that this

[1] POPULAR ASTRONOMY, **40**, 88, 1932.

brighter component is referred to whenever ζ Lyrae is mentioned.

In 1932 Whitford[2] reported that his measures of the difference in brightness between ϵ^1 and ϵ^2 showed no evidence of variability on several nights in that year.

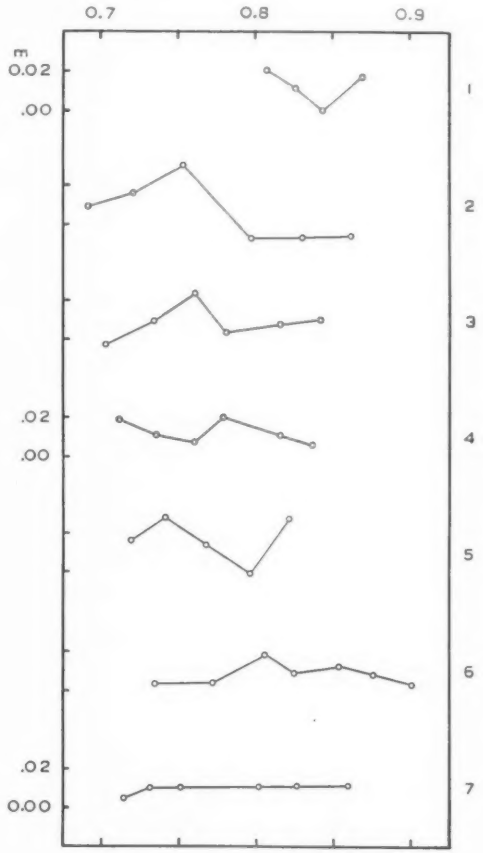


FIGURE 1

LIGHT CURVES OF ϵ^1 LYRAE.

Curves 1-5 were obtained in 1931 and curves 6 and 7 in 1934.

The two stars were again observed by the writer at the Lick Observatory in the summer of 1934. This paper will give further details of the observations in 1931 as well as present data obtained in 1934.

[2] *Ap. J.*, **76**, 213, 1932.

Observations in 1931

The observations of this year were made in two ways. On some nights ϵ^1, ϵ^2, and ζ were intercompared either in the order

$$5\epsilon^1\ 5\epsilon^2\ 10\zeta\ 5\epsilon^2\ 5\epsilon^1 \quad \text{or} \quad 5\epsilon^2\ 5\epsilon^1\ 10\zeta\ 5\epsilon^1\ 5\epsilon^2.$$

On other nights the measures were of the form $3\epsilon\ 6\zeta\ 3\epsilon$.[3]

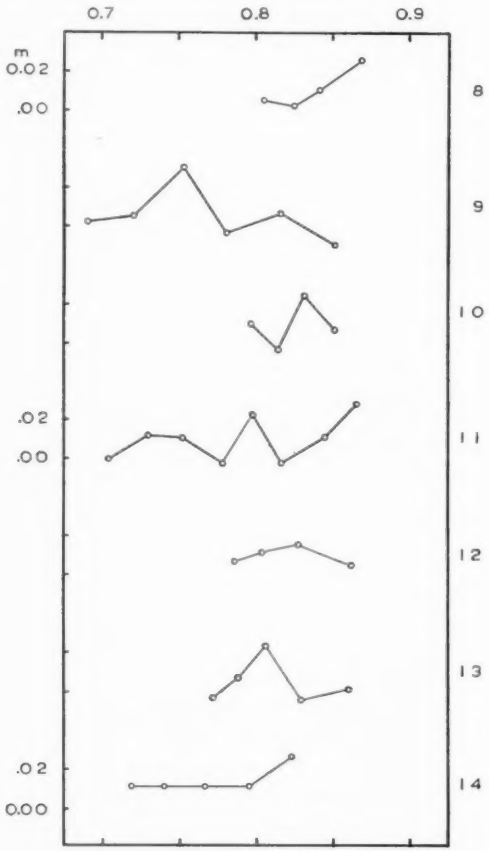


Figure 2
Light Curves of ϵ^2 Lyrae in 1931.

In order to reduce ζ to the approximate brightness of ϵ^1 and ϵ^2 the telescope lens was stopped down from 12 to 10.5 inches by means of a metal diaphragm. This reduced the brightness of ζ by $0^M.267$.

[3] When ϵ is used without superscript it means either ϵ^1 or ϵ^2.

In Figs. 1 and 2 the light curves obtained on individual nights are shown. The points plotted are either means of 3 measures of the form $3\epsilon\ 6\zeta\ 3\epsilon$ or of 2 measures of the form $5\epsilon^1\ 5\epsilon^2\ 10\zeta\ 5\epsilon^2\ 5\epsilon^1$. Curves 1-5, Fig. 1, show the variations in magnitude between ϵ^1 and ζ, and curves 8-14, Fig. 2, the corresponding changes between ϵ^2 and ζ.

Observations were obtained on the dates given below, the fractional part of the day being indicated at the top of each figure.

ϵ^1		ϵ^2	
Curve 1	J.D. 2426567	Curve 8	J.D. 2426567
2	568	9	568
3	571	10	569
4	577	11	570
5	579	12	572
		13	578
		14	579

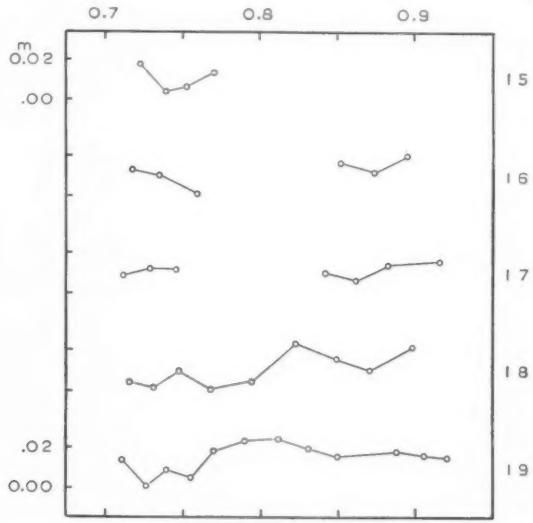


FIGURE 3
LIGHT CURVES OF ϵ^2 LYRAE IN 1934.

OBSERVATIONS IN 1934

The light curves for 1934 are shown in Fig. 1, curves 6 and 7 for ϵ^1, when compared with ϵ^1 or ϵ^2. Furthermore, a measure consisted of settings of the form $5\epsilon\ 10\zeta\ 5\epsilon$. There was no intercomparison of the three stars.

The light curves for 1934 are shown in Fig. 1, curves 6 and 7 for ϵ^1 and in Fig. 3, curves 15-19 for ϵ^2. The gaps in curves 16 and 17 represent times when it was necessary to interrupt work on ϵ^2 in order to carry out certain other observations on the photometric program. The points plotted are the means of two successive measures of the form

$5\epsilon\ 10\zeta\ 5\epsilon$, thus making the points of the same weight as those used for the curves of 1931.

Observations were obtained on the following dates:

ϵ^1		ϵ^2	
Curve 6	J.D. 2427643	Curve 15	J.D. 2427631
7	644	16	636
		17	637
		18	638
		19	639

The question of the suitability of ζ as a comparison star involved some tests in 1931 but it seemed desirable to test this matter somewhat more in detail in 1934. The tests made were as follows: On each of five nights a set was run intercomparing μ, ν^2, and ζ Lyrae. The form of the set was either

$$10\mu\ 10\zeta\ 20\nu^2\ 10\zeta\ 10\mu \quad \text{or} \quad 10\nu^2\ 10\zeta\ 20\mu\ 10\zeta\ 10\nu^2.$$

On one night two such sets were made. A sector reducing the light of ζ by $0^M.953$ was used. The measured differences in magnitude were as follows:

1934	$\mu - \zeta$ M	$\nu^2 - \zeta$ M
June 7	0.357	0.158
28	.351	.170
29	.343	.170
	.353	.168
July 3	.332	.172
4	.349	.170
Mean Δ M	0.348 ± 0.006	0.168 ± 0.003

The range of $0^M.025$ for $\mu - \zeta$ is too large to be satisfactory but the range of only $0^M.014$ for $\nu^2 - \zeta$ for the five nights and the range of only $0^M.004$ for the last four nights could hardly be achieved unless either ν^2 and ζ varied together in exact phase and with the same range or else that there was no appreciable variation in either. The latter alternative seems the more probable.

Discussion and Results

Curves 1-5 show the results of observations of ϵ^1 in 1931. It seems quite evident that we must conclude that at that time ϵ^1 was certainly variable with an amplitude of several hundredths of a magnitude. Curves 6 and 7 show little or no variation at the time of observation in 1934.

Curves 9, 10, and 11 and 13 show definite short-period variation of ϵ^2 in 1931, curves 12 and 14 show comparatively little change while curve 8 is merely corroborative of change. Curves 15, 18, and 19 likewise show evidence of short-period variation in 1934 while 16 and 17 are uncertain.

From this evidence it appears that we are dealing with two stars which are at times variable and at other times not variable. It is, therefore, quite possible that Whitford happened to make his observations when ϵ^1 and ϵ^2 were essentially constant in light.

When the mean curves for 1931 were published it had been assumed that the difference in the curves might be due to errors of observation, but, as greater experience was obtained, this was found to be improbable. Tests for accuracy were made by making measures on a single comparison star and grouping the measures in the same way as if two stars were being compared. It was then found that the probable error of a set (3 measures of 3c 6v 3c or 2 measures of 5c 10v 5c) seldom exceeded $\pm 0^{M}.003$ and more often was less. It is, therefore, practically certain that the differences in the curves represent real differences in the range of variation of the two stars. The diameter of the circles used in plotting the curves has a value of $0^{M}.003$, the approximate probable error of each point.

Unfortunately, both ϵ^1 and ϵ^2 are double stars the components of which are too close to be observed separately with the instruments thus far used. It is, therefore, impossible to decide whether one or both components in each double are involved in the irregular variation.

On the basis of the intercomparison of μ, ν^2, and ζ Lyrae it appears that μ is a variable star with a range of from $0^{M}.02$ to $0^{M}.03$ while ν^2 and ζ are suitable as comparison stars.

Goodsell Observatory, Carleton College, May 15, 1936.

Greek Astronomers During the Third Century B.C.

By A. WILLARD TURNER

Introduction

In this article we have attempted to outline the astronomical progress of the third century B.C., in so far as it relates to the contributions of the individuals identified with the subject. Strictly speaking, the title should probably be, "Hellenistic Astronomers and Leading Mathematicians of the Third Century B.C."

During this century, the brilliant mathematical genius of the Greeks achieved unprecedented heights, due largely to the remarkable activity of three great men, Euclid, Archimedes, and Apollonius. Although Aristarchus of Samos—one of the most eminent astronomers of antiquity—is associated with this period, the progress in astronomy proper was quite eclipsed by mathematical development.

Politically, Greece had been subjugated by Alexander the Great, and her civilization was already in decline. Intellectual pursuits which formerly centered around Athens were transferred to Alexandria, which city for the next 700 years remained the world's chief focal point of learning. Astronomy, continuing to strengthen the autonomous character it initiated during the previous century, became less encumbered by philosophic and metaphysical preconceptions, and less dependent upon

allied sciences. Even so, the subject was still treated in a theoretical way, and remained more or less indifferent to the intrinsic importance of observations.

This century was dominated by two men whose names are familiar to most students of science—Euclid and Archimedes. The geometer, Euclid, marked the first half of the century, during which time Aristarchus was the only astronomer of whom we have any substantial account. During the latter half, the mathematician and physicist, Archimedes, exerted an almost overpowering influence; though Eratosthenes and Apollonius deserve special mention in astronomical history, the former directly, and the latter indirectly.

Strangely enough, although records of the work of this century are more nearly complete and less uncertain than those of the preceding one, we are provided with practically no information concerning the personal lives of the great men of the period. This circumstance is rather unfortunate, for the contributions of outstanding thinkers can be more truly appreciated, perhaps, when we know something of the lives and characters of the men themselves. Possibly the extensive range and value of the subject matter of this period so absorbed chroniclers that the personalities involved received but transitory reference.

I. Euclid (Εὐκλειδης): c. 330 B.C. - c. 275 B.C.?

Euclid was chosen as teacher of Mathematics for the University of Alexandria, founded about the beginning of the third century B.C. His reputation rests chiefly upon his colossal work "The Thirteen Books of Euclid's Elements," so familiar even today as a text book in elementary geometry. This book has come down to us through Arab channels, and a manuscript of the "Little Astronomy" wherein it is included, is in the Bodleian Library. The Elements represented a comprehensive, exhaustive, and synthetic coördination of the geometry known at that time and, although much of the material was originally worked out by earlier geometers, the whole arrangement of the book and not a few theorems were entirely due to Euclid.

His contributions to astronomy include an extant book, "The Phaenomena," in which substantial reference is made to Autolycus' work.[1] In scientific philosophy Euclid adhered to Plato's doctrines, and consequently it was natural that he should devote himself chiefly to purely theoretical mathematics, and that his astronomical interests should be conditioned by the Platonic viewpoint.

Mediaeval writers frequently refer to him as Euclid of Megara, though this name applies to the Eleatic philosopher who lived in Plato's time. Of our Euclid's personal life we know very little, though tradition has endowed him with a mild and modest disposition, and has thrown other sidelights on his character through numerous recorded stories. One of these stories—though it may or may not be true—tells

[1] A. W. Turner: Popular Astronomy, April, 1936.

us that someone who had begun to read geometry with Euclid, when he had learned the first theorem, asked Euclid, "But what shall I get by learning these things?" Euclid called his slave and said, "Give him threepence since he must make gain out of what he learns."[2]

While the influence of Euclid's Elements upon mathematical teaching can scarcely be overestimated, the historical study of the development of logic is highly concerned with this same work.

II. ARISTARCHUS[3] (Ἀρίσταρχος) : c. 310 B.C. - c. 230 B.C.

In his encyclopaedic work on architecture (c. 15 B.C.) Vitruvius included Aristarchus amongst the few great men of antiquity whose knowledge was equally profound in all branches of learning. While he merits recognition chiefly as a mathematician and astronomer, he also wrote on vision, light, and colors, and was versed on almost all subjects of that time. Convinced that he has not received the recognition he deserves from students of astronomy, we shall confine our attention solely to his astronomical contributions.

Aristarchus was the first scientist to propose a method to measure the relative distances of the sun and the moon. Although the crude character of his instruments precluded results of high accuracy, it is generally agreed that his method was perfectly sound. Actually, for nearly two thousand years no better method was advanced. His extant treatise, "On the distances of the sun and the moon," has been translated into English by no less an authority than Sir T. L. Heath.

He is credited with the discovery of a new type of sun-dial, consisting of a concave hemispherical surface with a gnomon in the centre. Again, he made observations of a summer solstice in 281-280 B.C., though the relevant information is somewhat vague. He also made a determination for the apparent diameter of the sun as 1/720th part of the zodiacal circle, and estimated the period for the Great Year.[4]

However significant and important the above contributions were, we have not yet mentioned that paramount achievement which anticipated Copernicus' work. To name our astronomer "the ancient Copernicus" is a perfectly legitimate appellation, for it is a well-established fact that Aristarchus was the originator of the heliocentric hypothesis formulated by Copernicus seventeen centuries later. Thus, Aristarchus explained the apparent motion of the sun by affirming the annual revolution of the earth on the circumference of a circle having the sun as centre. His conception of the physical world implied the absolute fixity of the sphere of fixed stars and of the sun. Moreover he had a much truer appreciation of the relatively small size of the earth than his predecessors, for he regarded the sphere containing the earth's circular orbit of negligible

[2] Heath, T. L.: The Thirteen Books of Euclid's Elements, vol. I., p. 3.

[3] Turner, A. W.: Five Great Greek Astronomers, *Jour. Roy. Astron. Society Canada*, vol. XXIX, No. 4.

[4] It is not clear just what period he meant by this term.

size when compared with the sphere of fixed stars. Furthermore, it is generally agreed that Aristarchus accepted Heraclides' statement that the earth turns on its axis; this rotation was implied by assuming the sphere of fixed stars to be stationary.

The following sentence translated from Archimedes' writings may reassure the skeptical reader of the authentic origin of the heliocentric theory—*a fortiori* since Archimedes was a younger contemporary of Aristarchus. "His (Aristarchus') hypotheses are that the fixed stars and the sun remain unmoved, that the earth revolves about the sun in the circumference of a circle, the sun lying in the middle of the orbit, and that the sphere of the fixed stars, situated about the same center as the sun, is so great that the circle in which he supposes the earth to revolve bears such a proportion to the distance of the fixed stars as the center of the sphere bears to the surface."[5]

The naturally inquisitive reader may wonder why such a significant astronomical advance has not received more attention. References to Aristarchus' system by classical authors are so few and brief that we are inclined to think his idea was not only rejected but ignored as well. Perhaps any vestige of hope for the propagation or acceptance of this heliocentric hypothesis was buried when Hipparchus[6] flatly reverted to the geocentric theory. However we may account for Aristarchus' comparative obscurity, we could scarcely expect a theory which proved so repugnant to the minds of even the fifteenth century to be adopted naturally and enthusiastically in the third century B.C.

III. ARISTYLLUS (Ἀρίστυλλος)
TIMOCHARIS (Τιμόχαρις)
ARATUS (Ἄρατος)
} first half of century.

Mere passing references to these men are made in most scientific histories of the third century. Apparently, Aristyllus and Timocharis worked simultaneously in Alexandria, devoting themselves to the observational side of astronomy. Much of their work was of use to Hipparchus in the second century; for instance, Dreyer[7] tells us that the longitudes of the stars observed by Timocharis furnished the comparison data by which Hipparchus discovered the precession of the equinoxes. Aristyllus made some observations of the declination of Capella, and of the three stars in the tail of Ursa Major. We mention Aratus, a poet and scientist, because his poem "Phaenomena" exercised a deep influence on the thought of this period. The poem included descriptions of the risings and settings of the stars, and of weather signs, and was based partly on Eudoxus' work of the same name. Aratus was associated with the Peripatetic and Stoic schools in Athens.

[5] Heath, T. L.: The Works of Archimedes, p. 122.
[6] c. 180 B.C. - c. 125 B.C.
[7] Dreyer, J. L. E.: History of Planetary Systems, p. 203.

IV. ARCHIMEDES (Ἀρχιμήδης) : c. 287 B.C. - 212 B.C.

During the latter half of this century, Archimedes was the dominant figure in the whole scientific world. He is frequently regarded as the greatest mathematical genius of the ancients, though Heath would apply an equally strong superlative to Eudoxus, the originator of the homocentric theory of planetary motion.

Archimedes is familiar to many people for the ingenuity which he displayed in his attempt to discover whether or not King Hiero's crown contained the correct proportion of gold. Upon finding the answer while he was taking his bath, tradition tells us that he summarily rushed into the streets shouting, "Eureka, Eureka" (I have found it). Actually, he had discovered a law applicable to floating bodies, which is well known as the "principle of Archimedes."

His extreme originality led to many practical inventions, such as the water-screw and the compound pulley, and his services were continually in demand by the government. Dynamics, statics, and hydrostatics were immeasurably enriched through his work; though Archimedes himself thought most highly of his abstract speculations in pure mathematics. Consequently, he requested that the figure of a sphere inscribed in a right cylinder be drawn on his tomb, since he considered his proof that their volumes were in the ratio of 2 : 3 to be his greatest achievement.

Notwithstanding his tremendous activity in Mathematics and Physics, he wrote a book on the construction of a celestial sphere, and made an orrery[5] and a sphere of the stars. The book was lost, but the two instruments were subsequently taken to Rome and kept there for two or three centuries.

Archimedes' main work is connected with his birthplace, Syracuse, though he did attend the Alexandrian school. Despite his practical and mechanical genius, Archimedes' philosophy was akin to that of Plato, and the application of knowledge to practical use did not receive his commendation—so that his philosophic belief and his life work present a curious anomaly.

V. ERATOSTHENES (Ἐρατοσθένης) : c. 273 B.C. - c. 192 B.C.

Eratosthenes, who was born at Cyrene about 273 B.C., received his early education at Alexandria, and was then appointed librarian of the University. He was a most versatile man, being a distinguished scholar in science, literature, and philosophy, a recognized philologist, and an accomplished athlete. His philosophic outlook was probably predicated by the Platonists of Athens and the Stoics. Unfortunately, when ophthalmia deprived him of his eyesight about 192 B.C., rather than live when he could no longer read, he committed suicide by self-imposed starvation.

His scientific interests lay chiefly in astronomy and geodesy and the measurement of the circumference of the earth was the outstanding

[5] A clockwise system for planetary motion.

achievement with which history links his name. He constructed several astronomical instruments, and wrote on many subjects, including partial and total eclipses, tropic and polar circles, and the sizes and distances of the sun and the moon. It is probable that he determined the obliquity of the ecliptic as 23° 51′ 20″.

The method by which Eratosthenes estimated the circumference of the earth utilized the same basic principle as that which underlies modern determinations. He observed that the sun cast no shadow in the bottom of a well at Syene at noon on the day of the summer solstice. In Alexandria at the same time, the shadow cast[9] gave the sun's zenith as 7° 15′, or, approximately 1/50 of four right angles. As Alexandria and Syene were on practically the same meridian, and the distance between them was known to be 5000 stadia, this distance was taken to be 1/50 of the earth's circumference, making the latter 250,000 stadia. Apparently, Eratosthenes revised this figure, and gave 252,000 stadia as his final estimate. Since it is not known for certain exactly what length was meant by the stadium, one cannot dogmatize about the accuracy of the result. Nevertheless, according to Heath,[10] if we grant the most probable assumption concerning the length of the stadium which he used, his result for the diameter of the earth is equivalent to about 7850 miles—about 50 miles less than the actual polar diameter. In any case, Eratosthenes' work in this connection was a brilliant example of his ability, and a most remarkable computation to be made over 2000 years ago.

VI. Conon (**Κόνων**): flourished about 260 B.C.[11]

Conon of Samos contributed to mathematics and astronomy, though we know very little of the work which he carried on at Alexandria. In mathematics, he may have invented the curve now known as Archimedes spiral,[12] and may have investigated the intersections of two conics. His astronomical work of seven books included Chaldean observations and a calendar which gave the risings and settings of the fixed stars, as well as forecasts of a meteorological nature. It is said that he named the constellation Berenice's Hair in honor of the wife of King Ptolemy III.

VII. Apollonius of Perga (**Ἀπολλώνιος**): c. 262 B.C.

Of this mathematician's life we know very little, save that he studied at Alexandria, and may have lectured there. Born about 262 B.C., he was a younger contemporary of Archimedes and Eratosthenes.

Apollonius ranks as one of the greatest geometers of antiquity, his work, together with that of Euclid dominating geometry for 2000 years. In his most important work on Conic Sections, he introduced the terms

[9] Probably by an upright gnomon.
[10] Legacy of Greece. Edited by R. W. Livingstone. p. 127.
[11] D. E. Smith: History of Mathematics, vol. I, p. 107.
[12] Lamb, H.: Infinitesimal Calculus, p. 308.

ellipse, hyperbola, and parabola, and treated his subject so very thoroughly that his successors could add very little. Originally, there were eight books of the Conics, of which the eighth has been lost, the first four have survived in Greek, and the remaining three in Arabic. Of the bearing of this work on astronomy, Whewell writes: "If the Greeks had not cultivated Conic Sections, Kepler could not have superseded Ptolemy."[13]

Apollonius' direct contributions to astronomy are not known with any certainty, though more than one commentator[14] mentions his book on the stations and regressions of the planets. According to Heath,[15] he is said to have done special work concerning the moon, and, also, to have originated the hypothesis of planetary motion advanced by Tycho Brahe.

Conclusion

In the history of astronomy during this century we have noted the significance of the Alexandrian school which became the chief intellectual center of the world, thus overshadowing Athens, the seat of Plato's Academy and Aristotle's Lyceum. Astronomical progress was not very marked, due largely to the emphasis placed upon geometrical development and general mathematical analysis. Nevertheless, the foundations laid in geometry were destined to play an important rôle in later astronomical advance, and might be regarded as an ancillary aid to astronomy proper.

The outstanding individual astronomer of this period was Aristarchus, and we can only regret that his Copernican conception met with the hostility of traditional prejudice and philosophical disfavor. Had his ideas been seriously considered, the subsequent history of astronomy would doubtless have been a different one. However interesting speculations concerning the "might-have-beens" of scientific history may be, they are probably rather futile when measured against the value of actual recorded fact. At this stage of its development, astronomy required observational data to test its theories and promulgate its hypotheses, and stood waiting for Hipparchus.

Dominion Observatory, Ottawa, Canada, March, 1936.

[13] Sedgwick and Tyler: A Short History of Science, p. 87.
[14] E.g., W. W. R. Ball, Sedgwick and Tyler.
[15] Heath: Aristarchus of Samos, pp. 269, 274.

Planet Notes for July and August, 1936

By CLIFFORD E. SMITH

Note: All times, unless otherwise stated, are Central Standard Time.

The *Sun* will be moving in a southeasterly direction from the western part of Gemini across Cancer to central Leo. On July 3 at 2:00 P.M. the earth will be at aphelion; that is, the earth will be at the place in its orbit farthest from the sun. The position of the sun on July 1, August 1, and August 31 will be respectively:

R.A. $6^h\,39^m$, Decl. $+23°\,9'$; R.A. $8^h\,44^m$, Decl. $+18°\,8'$; and R.A. $10^h\,36^m$, Decl. $+8°\,48'$.

The phenomena of the *Moon* will occur as follows:

Full Moon	July	4	at 12	NOON
Last Quarter		11	" 10	A.M.
New Moon		18	" 9	A.M.
First Quarter		26	" 7	A.M.
Full Moon	Aug.	2	" 10	P.M.
Last Quarter		9	" 3	P.M.
New Moon		16	" 9	P.M.
First Quarter		24	" 12	MIDNIGHT
Perigee	July	11	" 3	P.M.
"	Aug.	6	" 10	A.M.
Apogee	July	25	" 9	A.M.
"	Aug.	22	" 3	A.M.

On July 4 there will be a partial eclipse of the moon.[1] "It will be invisible at Washington; the beginning visible generally in the Antarctic Ocean, the Indian Ocean, Australia, the western and southwestern parts of the Pacific Ocean, Asia, with the exception of the extreme northern part, and the southern and eastern parts of Africa; the ending visible generally in the southeastern part of the Atlantic Ocean, Africa, with the exception of the northwestern part, eastern Europe, Asia, with the exception of the extreme northeastern part, Australia, the Antarctic Ocean, the Indian Ocean, and the southwestern and western parts of the Pacific Ocean."

Mercury will be moving in an easterly direction from the eastern part of Taurus across Gemini, Cancer, and Leo to the western part of Virgo. At the beginning of July it will be a morning star rising about an hour and a half before the sun. It will rapidly approach the sun in apparent position, however, and superior conjunction will occur on July 23 at 9:00 P.M. At the end of this period it will be an evening star again setting about an hour and a half after the sun. Its distance from the earth will be increasing from about 86 to about 125 million miles toward the end of July. After that time its distance will decrease so that at the end of August its distance from the earth will be about 95 million miles. The corresponding change in apparent diameter will be from about 7.0 to about 5.0 seconds of arc, and then up to 6.6. On July 15 at 11:00 A.M. Mercury will be in conjunction with Mars (Mercury 13′ S). Mercury and Mars, however, will be too near the sun in apparent position to be seen. Likewise the conjunction of Mercury with the moon on July 17 at 8:00 P.M. will be invisible. On August 1 at 7:00 A.M. conjunction with Venus will occur (Mercury 22′ N). This conjunction also will occur when Mercury and Venus are rather near the sun in apparent position. On August 17 at 10:00 A.M. Mercury will be in conjunction with Neptune (Mercury 48′ S). The August conjunction with the moon will occur on the 19th at 1:00 A.M. (Mercury 5°.6 N). The position of Mercury on the first day of July and the last day of August will be, respectively: R.A. $5^h\,8^m$, Decl. $+20°\,35'$, and R.A. $12^h\,12^m$, Decl. $-3°\,7'$.

Venus will be rather near the sun in apparent position to be of interest, since superior conjunction occurred on June 29. By the end of August, however, it will be in eastern Leo and it will set about an hour after the sun. On the last day of August its distance from the earth will be about 150 million miles and its

[1] POPULAR ASTRONOMY, January, 1936, p. 28.

apparent diameter will be about 10.4 seconds of arc. The August conjunction with the moon will occur on the 18th at 7:00 A.M. (Venus 6°.7 N). Conjunction with Neptune will occur on August 23 at 2:00 P.M. (Venus 26′ N).

Mars will be a morning object in Gemini during this period but it will be too near the sun in apparent position to be of interest. By the end of August it will rise about an hour and a half before the sun.

Jupiter will be an evening object in southern Ophiuchus. Early in the period it will set about 3:00 A.M., but by the end of August it will set around midnight. Its distance from the earth will vary from about 410 to about 470 million miles, and its apparent diameter will decrease from about 42 to about 36 seconds of arc. Its apparent motion among the stars will be retrograde to August 11, and thereafter it will be easterly. Jupiter will be in conjunction with the moon three times during this period: on July 2 at noon, July 29 at 5:00 P.M., and on August 26 at 2:00 A.M. (Jupiter will be about 2°.0 N in each case).

Saturn will be near the border of Pisces and Aquarius. At the beginning of July it will rise about 11:00 P.M. for northern observers. The time of rising will be earlier each day until at the end of August it will rise about 7:00 P.M., Local Standard Time. Its apparent motion among the stars will be retrograde practically the entire period. The distance of Saturn from the earth will decrease from about 866 to about 800 million miles, and the change in apparent diameter will be from about 16 to about 17 seconds of arc. Conjunction with the moon will occur on July 9 at 7:00 P.M. and on August 5 at midnight (Saturn about 8°.0 S in each case).

Uranus will be a morning object in southwestern Aries. At the beginning of July it will rise about 2:00 A.M., Local Standard Time, for northern observers. The time of rising will be about 4 hours earlier by the end of August. During this period the distance from the earth to Uranus will vary from about 1890 to about 1790 million miles and the change in apparent diameter will be from about 3.4 to about 3.6 seconds of arc. Quadrature west of the sun will occur on August 1 at 6:00 P.M. Conjunction with the moon will occur on July 12 at 11:00 P.M. and on August 9 at 5:00 A.M. (Uranus about 4°.8 S in each case). The position of Uranus on August 1 will be R.A. $2^h\ 29^m$, Decl. +14° 13′.

Neptune will continue to be an evening object in southeastern Leo near χ Leonis. Its apparent motion among the stars will be easterly. During the middle of this period its distance from the earth will be about 2900 million miles and its apparent diameter will be about 2.4 seconds of arc. At the beginning of July it will set about 4 hours after the sun. During this period, however, it will approach the sun in apparent position so that by the end of August it will set practically with the sun. As stated in the notes on Mercury, Neptune will be in conjunction with Mercury on August 17 at 10:00 A.M. (Neptune 48′ N). Conjunction with the moon will occur on July 22 at 11:00 A.M. and on August 18 at 8:00 P.M. (Neptune about 6°.5 N in each case). The position of Neptune on August 1 will be R.A. $11^h\ 7^m$, Decl. +6° 47′.

Finding Neptune without the Aid of Circles

Neptune may easily be located this month (May) without the aid of circles or an ephemeris. Always below naked-eye visibility, this planet is not likely often to be observed through small, simply-equipped, telescopes.

This spring some of the astronomy students of the local university have been following the old god of the sea as he wanders among the faint stars. They have

done this easily (and with a great deal of pleasure) with the aid of the *American Ephemeris* and the instrumental circles. χ Leonis has been used as the guide star.

On May 10 it was noticed that Neptune was in a line of three stars of about its own brightness and that the guide star (magnitude 4.7) could easily be brought into the same field with the entire line when an eyepiece taking in a strip of sky 45′ in width was used. A glance at the ephemeris showed that it would be in almost exactly the same position again on June 10 and for a few days after that, as it will change from retrograde to direct motion in the meantime.

These suggestions are made with the idea that many with small telescopes may have the pleasure of locating Neptune and following its motion for a while. The field of view in an inverting telescope without the use of a zenith prism if χ Leonis is placed near the lower, left edge of the field will show a line of three stars, about the same brightness as Neptune, in the middle of the field. In this line and south of (above) the third star is the planet sought. The line of stars runs roughly north and south, but its slant will, of course, depend upon the position in the sky when observed. The line will be vertical when near the meridian.

The procedure is as follows: Locate χ Leonis without optical aid. In the finder, if the telescope is equipped with one, both χ and 59, below and to the right of it, may be seen, but knowledge of the telescopic inversion and the difference in brightness will take care of difficulties. In the larger telescope bring χ near the edge of the field between the apparent left and lower portions. The line of stars including the planet will easily be found. Neptune may have moved a little from the line if you first observe a few days after June 10 but you should have little difficulty in spotting it. If difficulties do arise, bring ephemeris position of the planet to the center of the field and diagram the brighter objects seen. A few evenings later one of these will be displaced somewhat. That's Neptune.

J. Hugh Pruett.

University of Oregon, Eugene, Oregon, May 10, 1935.

OCCULTATION PREDICTIONS

(Taken from the *American Ephemeris.*)

Occultations Visible in Longitude +72° 30′, Latitude +42° 30′.

Date 1936		Star	Mag.	Immersion: Greenwich C.T. h m	Immersion: a m	Immersion: b m	Immersion: Angle E from N °	Emersion: Greenwich C.T. h m	Emersion: a m	Emersion: b m	Emersion: Angle E from N °
July	1	42 Lib	5.1	4 35.7	−1.9	−2.6	146	5 24.0	−0.5	0.0	223
	2	22 Sco	4.9	1 42.2	−1.5	−0.9	143	2 43.6	−2.3	+0.8	233
	7	53 B.Aqr	6.5	5 22.8	−2.4	+0.1	114	6 9.7	−0.6	+2.4	189
	9	6 G.Psc	6.2	4 6.7	−0.8	+0.9	115	4 44.7	−0.3	+2.8	189
	11	136 B.Psc	6.5	3 53.1	+0.4	+2.4	13	4 25.8	−1.3	+0.7	298
	28	64 G.Lib	5.7	1 28.4	−1.8	+0.2	50	2 24.4	−1.8	−2.7	330
	29	24 G.Sco	6.2	0 27.8	−2.0	−0.3	106	1 55.8	−2.0	−0.7	269
	29	88 B.Oph	5.9	22 38.7	−1.5	+1.2	88	23 59.8	−1.7	+0.2	288
	29	26 Oph	5.8	22 50.6	−2.0	+1.9	60	23 57.1	−1.4	−0.4	314
	31	9 Sgr	5.9	3 34.6	−1.1	+0.8	34	4 33.3	−2.2	−2.0	301
	31	ν^3 Sgr	5.0	23 31.2	−1.7	+2.9	29	0 13.8	−0.9	−0.3	319
Aug.	1	168 B.Sgr	6.3	3 38.7	−2.1	−0.4	97	4 50.5	−1.1	+0.3	225
	3	95 B.Cap	6.0	6 45.8	−1.6	−0.6	84	7 50.1	−0.5	+0.5	216
	6	16 Psc	5.6	4 32.9	−1.2	+1.6	71	5 41.0	−1.0	+1.7	224
	10	τ Ari	5.2	4 56.0	+0.1	+1.5	74	5 51.5	−0.2	+1.6	249
	14	56 Gem	5.2	7 20.2	..	..	21	7 34.4	..	..	350

	24	43	B.Lib	5.8	0	27.2	—1.4	—1.1	88	1	43.6	—1.0	—1.9	290
	28	117	B.Sgr	5.8	4	19.7	..	..	153	4	31.2	..	..	171
	30	53	B.Aqr	6.5	22	19.4	—0.3	+1.3	98	23	14.6	—0.8	+2.0	223
	31	72	B.Aqr	6.5	5	44.3	—1.2	—0.3	70	6	51.4	—0.6	+0.1	228

Occultations Visible in Longitude +91° 0′, Latitude +40° 0′.

July	1	42	Lib	5.1	4	4.3	—2.0	—2.0	146	5	4.0	—1.8	+0.2	233
	7	53	B.Aqr	6.5	4	49.5	—1.3	+1.0	104	5	46.2	—1.1	+2.2	207
	15	300	B.Tau	6.2	8	52.0	+0.1	+1.2	88	9	45.7	0.0	+1.5	250
	28	64	G.Lib	5.7	0	41.5	—2.7	+0.8	68	1	55.2	—1.8	—1.8	324
	28	24	G.Sco	6.2	23	55.6	—1.4	—0.2	128	1	15.8	—2.3	+0.5	260
	29	41	G.Sco	6.3	3	49.9	—1.6	—0.4	68	5	5.7	—1.6	—1.9	293
	30	137	B.Oph	6.3	5	57.1	—2.0	—2.6	133	6	41.7	+0.2	+0.8	210
	31	9	Sgr	5.9	3	3.6	..	..	24	3	49.9	..	..	321
Aug.	1	168	B.Sgr	6.3	2	59.8	—2.0	+0.6	90	4	21.8	—1.9	+0.6	242
	3	95	B.Cap	6.0	6	14.2	—1.7	+0.7	61	7	31.9	—1.4	+0.3	238
	6	16	Psc	5.6	4	13.8	—0.5	+1.8	59	5	17.7	—0.9	+1.6	242
	6	19	Psc	5.3	10	37.5	—2.2	—1.8	108	11	25.7	—0.4	+2.4	190
	7	136	B.Psc	6.5	11	4.1	—2.4	—2.0	111	11	52.9	—0.7	+2.8	191
	8	101	Psc	6.2	10	21.7	—1.7	+1.2	59	11	40.5	—1.7	+0.5	245
	10	τ	Ari	5.2	4	58.5	+0.5	+1.4	63	5	48.3	+0.2	+1.2	264
	14	61	Gem	5.9	9	21.5	..	..	27	9	41.4	..	..	345
	23	43	B.Lib	5.8	23	54.7	—2.2	—0.6	93	1	23.1	—1.8	—1.7	295
	25	32	B.Sco	5.4	3	58.4	..	..	170	4	10.5	..	..	190
	28	117	B.Sgr	5.8	3	34.7	—2.4	—1.3	113	4	35.0	—0.6	+0.8	211
	31	72	B.Aqr	6.5	5	18.3	—1.3	+0.9	47	6	32.3	—1.5	—0.1	248

Occultations Visible in Longitude +120° 0′, Latitude +36° 0′.

July	4	117	B.Sgr	5.8	9	25.4	—1.9	—0.6	87	10	40.5	—0.9	0.0	235
	5	253	B.Sgr	6.0	6	41.3	—2.2	—0.3	123	7	35.4	—1.6	+2.4	204
	7	72	B.Aqr	6.5	12	8.4	—2.0	—0.7	89	13	10.6	—0.4	+1.3	205
	27	9	G.Lib	6.5	6	21.3	—1.4	—2.9	147	7	9.5	0.0	—0.1	232
	29	41	G.Sco	6.3	2	42.6	—2.5	+0.7	82	4	12.2	—2.3	—1.0	299
	30	137	B.Oph	6.3	4	57.6	—2.4	—0.7	112	6	18.4	—1.8	+0.1	241
	31	7	Sgr	5.5	1	28.4	—2.1	+3.4	35	2	8.4	—0.2	—1.2	330
	31	9	Sgr	5.9	1	51.6	—1.6	+2.2	57	2	56.2	—1.2	—0.1	306
Aug.	1	168	B.Sgr	6.3	2	16.5	—0.7	+0.7	111	3	21.7	—1.6	+1.7	238
	1	199	B.Sgr	6.4	9	18.9	—0.3	+1.0	28	10	12.6	—1.5	—1.9	287
	3	95	B.Cap	6.0	5	23.5	—1.4	+2.1	39	6	33.4	—2.1	+0.6	273
	6	19	Psc	5.3	9	34.9	—1.7	+1.3	64	10	51.3	—1.4	+1.5	224
	7	136	B.Psc	6.5	9	58.9	—1.7	+1.4	69	11	13.8	—1.4	+1.7	223
	8	101	Psc	6.2	9	43.1	—0.3	+2.8	20	10	39.4	—2.1	+0.4	279
	25	32	B.Sco	5.4	3	1.7	—2.4	—2.3	143	4	1.9	—1.6	+0.4	228
	28	117	B.Sgr	5.8	2	27.9	—2.1	+0.4	102	3	50.0	—2.2	—1.0	238
	30	47	B.Cap	6.2	5	40.4	—2.3	+0.3	86	6	54.5	—1.2	+1.2	216
	31	72	B.Aqr	6.5	4	36.9	—0.9	+2.8	12	5	27.9	—2.6	—0.3	292

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Comet Notes

By G. VAN BIESBROECK

COMET PELTIER (1936*a*). The first new comet of the year has just been announced. It was found by Leslie C. Peltier of Delphos, Ohio. This enthusiastic variable-star observer is at the same time a most industrious comet hunter. This is the fifth new comet found by Mr. Peltier. In the morning of May 15 he modestly wired to the writer, "Verify extremely slow motion ninth magnitude comet, $23^h\,59^m$, $+74°$." I knew at once that this would prove a genuine discovery. Peltier knows the sky and recognizes unexpected visitors, but in this case the discovery was especially difficult. The object moved so slowly that there apparently remained a shadow of doubt lest there was perhaps confusion with some long-known nebulous object.

FIGURE 1
COMET PELTIER (1936*a*).
Enlarged four times from a twenty-minute exposure
with 24-inch reflector of the Yerkes Observatory.

Since the sky was clear that evening, I had no difficulty in picking up the newcomer and determining its exact position with the 40-inch refractor:

1936 May 16.16758 U.T. $23^h\,51^m\,59^s.23$, $+73°\,26'\,53''.3$. Magnitude 9.
Daily motion, in right ascension $+91^s$, in declination $-5'\,50''$.

The result was transmitted at once to the central bureau of cometary information at Harvard College Observatory, Cambridge, Massachusetts, where the ob-

ject could be recorded photographically before the end of the same night.

The comet can be fairly well seen in a 4-inch telescope. Its appearance is seen from Figure 1, which is reproduced from a plate taken here on May 17 with the 24-inch reflector: it shows the sharp nucleus surrounded by a diffuse coma streaming out into a tail some 10′ long in a direction nearly opposite to that of the sun.

Something is already known at the time of writing about the future course of this comet. From observations on May 16, 17, and 18 Whipple and Cunningham at Harvard have deduced the following parabolic orbit:

Perihelion passage 1936 July 4.85 U.T.
Distance from perihelion to node $\omega = 153° 49′$
Longitude of node $\Omega = 127\ 06$
Inclination $i = 75\ 34$
Perihelion distance 0.995 astronomical units.

This gives the short ephemeris:

1936	α h m s	δ ° ′	Br.
May 24	0 2 00	+72 40	1.00
28	0 9 06	71 51	
June 1	0 13 54	70 53	
5	0 17 18	+69 38	2.84

These elements are evidently uncertain since they depend on a very small arc, but it is evident that for northern observers the comet will remain visible during the months of June and July, and that it will increase in brightness since on June 5 it will be nearly three times as bright as on May 24. In the fall the comet, which moves in a highly inclined orbit, will become a morning object ultimately disappearing in the southern hemisphere.

Compared with this new comet, the other ones now under observation are extremely inconspicuous objects. Both periodic comets Comas Solá (1927 III) and Schwassmann-Wachmann (1929 I) are so faint that they will not be followed much longer. Also Comet Van Biesbroeck (1935 *d*) has been very disappointing. While theoretically at maximum in May, it was recorded here a couple of times as faint as a star between 16th and 17th magnitudes. The correction to the ephemeris on page 269 is still small.

Another periodic comet that has been disappointing on account of its faintness is Schwassmann-Wachmann (1925 II). Through an oversight, the ephemeris was not published until after opposition but the writer could not find a trace of the object during the month of May.

Williams Bay, Wisconsin, May 19, 1936.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editors may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

The Infinite Intersections of Traveling Light

In reference to the article "The Infinite Intersections of Traveling Light" by George N. Cole which appeared in the February issue of Popular Astronomy, I have a possible explanation.

It is clearly evident that all we know about light is derived from its generation or interaction with matter. We have workable theories about how it is generated, but all the experiments we make upon it require material instruments. Clearly we may know a great deal about the origin of the light in a star and its effect on our eyes or instruments but we really know nothing about it in the space between. We can speculate, it is true, but our speculations are not subject to test. We cannot be sure that the known phenomena of light are not produced by the conditions of any experiment that we perform upon it. Perhaps the present confusion as to whether light is a wave or a particle is due to this.

Since we do not know the nature of light in free space Mr. Cole's intersections may be illusory and need no explanation. Since light is not matter, we are not necessarily justified in applying the results of the action of light upon matter to the results of the action of light upon light, *i.e.* an intersection. Even the experiment in which two light waves (if it is a wave) produce darkness when they are out of phase does not prove that one light ray has any effect on another. It is possible that the effect of one ray on our instruments is undone by the other, and the result is nil.

As for Mr. Cole's deduction that light attracts light; I believe that it is based upon a misconception. As I understand it, the sun bends light from its normal path, not by attracting it, but by warping the space in which the light travels.

JOHN BUDDHUE.

99 South Raymond Avenue, Pasadena, California, May 1, 1936.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

Meteoric astronomy has suffered a great loss in the recent death of A. King, of Ashby, England, for many years the author of "Meteor Notes" in *The Observatory*. Mr. King was one of that group of amateur astronomers which has for several generations made notable contributions to astronomy in the British Isles. He is probably best known for his excellent fireball paths, large numbers of which he computed and published, though his contributions to the accurate determination of the principal shower radiants and their comparison with theory are also fine pieces of work. He and the writer have been friends and in close touch for over a decade, and his cordial coöperation on a number of occasions has been most valuable. His personal influence and accurate work did much, in recent years, to keep meteoric astronomy at its present high level in his native land.

Among current reports of interest are those for six nights in January and six in February made by J. Fraser Paterson of Broken Hill, Australia. The notable features were (1) the appearance of 18 meteors on January 19 between 8:00 and 9:00 (sky perfect), and (2) the appearance of 15 meteors on February 23 between 8:10 and 9:10 (sky perfect), 13 of them coming from a radiant in the vicinity of ϵ Carinae. Careful observations should be made on this date in the future, and the radiant of this minor shower accurately determined.

Four reports have reached us on the Quadrantid meteors of January. Joseph Leerman, of Baltimore, Maryland, on January 3-4, 13:30 to 15:30, saw 10 meteors,

all of magnitude 1 or 2. F. W. Smith, of Glenolden, Pennsylvania, on the same night saw 2 meteors, one a Quadrantid of 1st magnitude, from 15:00 to 16:00, the sky being clear. Prof. J. Thurston Kent, of Russellville, Arkansas, on January 2-3, from 12:50 (when the sky was fair) to 13:57 (when the observations were stopped by clouds) saw 5 meteors, all of magnitude 1 or 2. H. Inouye of Nagoya, Japan, on December 31-January 1 from 14:27 to 15:27 observed 12 meteors. Six certain Quadrantids gave a good radiant (A.M.S. No. 2918) at $\alpha = 230°$, $\delta = +49°$; two of the other six might have been Quadrantids.

Only two American reports have so far come in on the Lyrids: Joseph Leerman, observing in Baltimore, saw 5 meteors between 12:55 and 14:55 on April 20-21, and only 2 between 12:55 and 13:55 on April 22-23. City illumination certainly interfered. The Louisville Astronomical Society had better luck on April 20-21, when 9 members worked at the home of Dr. W. L. Moore, four miles from Louisville, Kentucky. Observing from 11:30 to 14:30, the first hour partly cloudy, the rest of the time fairly clear, they counted a total of 110 meteors, the observers facing different parts of the sky as a rule. This gave an uncorrected average of 12 meteors for one observer for 3 hours, or 4 per hour. With the usual correction for clouds, the rate would rise to about 5 per hour. A few meteors were plotted, but attempts to photograph them were unsuccessful.

Mr. Eppe Loreta, of Bologna, Italy, observed on April 17, 18, 19, and 21. He plotted 4, 2, 7, and 9 meteors respectively on these nights. His counts on two nights were as follows: April 19-20, from 20:30 to 2:55 T.M.U. (*i.e.* 8:30 to 14:55), 20 Lyrids and 37 sporadics; April 21-22, during exactly the same interval, 50 Lyrids and 62 sporadics. Allowing for 25 minutes out due to clouds on April 19-20, the total rates were 9.5 per hour on the first night and 17.4 per hour on the second. The two American observations reported did not include the night of April 21-22, on which there was a clearly defined maximum.

Loreta also sent in excellent drawings of a beautiful drifting train of a fireball which appeared at 13:33 on the night of April 21-22. By aid of an opera glass he followed it for its total duration of 120 seconds, with remarkable changes of form as it drifted. The very interesting and complete record secured for this train indicates that it is wise to keep an opera glass at hand while observing meteors. Trains lasting an appreciable time are so rare that observers should spare no effort to plot them with all precision at half-minute intervals, or at one-minute intervals if they endure for many minutes.

So far we have received no reports on the Eta Aquarids of early May. However, a most brilliant fireball was observed from Salisbury, North Carolina, on May 4-5 at 15:03 E.S.T. It was also visible as far north as Lynchburg, Virginia. Additional observations are greatly desired. The object seems to have been brighter than the moon.

Work has been continued on the great Pennsylvania-New Jersey fireball of March 13-14, 14:47 E.S.T., which was probably the most brilliant seen here for many years. Over 200 reports were received, and the computations are now nearing an end. It seems fairly certain that some fragments fell into the ocean not far from Sandy Hook, New Jersey. The accompanying sound phenomena were very striking over northern New Jersey.

In the discussion of an unexpected meteor shower observed by Professor Khan in India in November, 1935, (see "Meteor Notes" for February, 1936, p. 89) parabolic elements were published for the stream with the radiant at γ Monocerotis, this position for it being given in Professor Khan's original report. However, there being ambiguity as to what star is γ, I later wrote to Professor Khan for

verification of the position; he replied that the γ he referred to is the star marked α on the AMS charts as well as in other atlases in our library. This makes the radiant position $\alpha = 114°.5$, $\delta = -9°.4$. He tells me in the same letter, however, that a better representation of the entire shower would be given if the radiant were adopted as $\alpha = 110°$, $\delta = -5°$ (the corrected value for AMS radiant No. 2917). This means that my original orbit, based upon a misunderstanding, is useless, as are the comments which accompanied it. It is indeed strange that star atlases are not uniform in their designations of stars.

Parabolic orbits have now been computed for both the positions given above. The elements are as follows:

Date	i	☊	π	q	Radiant
1935 Nov. 21.29	115°.0	58°.5	135°	0.61	(114°.5, −9°.4)
	114.5	58.5	144	0.46	(110, −5)

We have further information on this shower through the Hydrographic Office, U.S.N. The Commanding Officer of *U.S.S. Canopus* reported that in Manila harbor on November 21 a meteor shower was observed continuing from 18:40 to 19:10 G.M.T. Meteors were seen at about 30-second intervals bearing about 150° at an altitude of about 45°. These would fit Professor Khan's radiant fairly well. We thus have a full confirmation of the short duration and exceptional richness of this shower, and incidentally information as to the territory over which it was visible.

As these are the last notes which will reach our observers before the summer meteor showers, certain routine matters should be called to their attention. The moon is full on August 3 and at last quarter on August 9; hence the conditions on July 28, when the Delta Aquarids are due at maximum, will be good late in the night, when most of the meteors will appear. Observations of the Perseid maximum on August 11, two days after last quarter, will be somewhat hampered by moonlight, but not seriously. All interested in meteors are urged therefore to observe on the dates July 26-30 and August 9-14, so that full records of these most important showers can be obtained. Because of the interesting results from our meteor heights found from Leonid campaigns, we are most desirous of securing many duplicate plots. Observers are requested to make simultaneous observations wherever possible, with this in mind. Simultaneous photographic work would be particularly valuable. The dates mentioned are most favorable as the hourly rates are high. We shall be glad to give advice by letter to persons planning duplicate observations, as they cannot be successfully made without careful preparation and full understanding of the points involved.

The months of July and August should be ideal ones for resumption of work by our inactive sections and members. Maps, blanks, and bulletins should be asked for in advance, so that they will be in the hands of the observers well before the times of showers.

Flower Observatory of the University of Pennsylvania,
Upper Darby, Pennsylvania, May 15, 1936.

Another Fictitious Meteoric Crater

By C. C. WYLIE

The following note appeared in the *Chicago Daily Tribune* for Thursday, April 2, 1936. It was brought to my attention by a student in the course in Practical Astronomy.

"Linton, Ind., April 1 (Special). A search by hundreds of persons today for the flash of light and the explosion which shook the countryside last night revealed that a meteor had almost scored a bull's eye on the monument erected near here to mark the center of population in the United States.

"On the farm of Fred Stretelmeir half a mile east of the monument the searchers found a six foot square crater hole. H. A. Kramer, Linton rural mail carrier, the first to find the hole, said mud had been thrown a distance of 50 feet from the crater.

"The noise from the falling body was heard for a radius of several miles. Nearby homes were shaken and windows shattered. Powder magazines in and near Linton were first inspected but were found to be intact.

"Prof. C. A. Malott of Indiana University was notified and will make an effort to recover the meteor. He said it was unusual to find the crater of a meteor."

Another note, evidently sent out later, appeared in the *Indianapolis Star* for Thursday, April 2, 1936. This clipping was sent to Dr. C. H. Gingrich, Editor of POPULAR ASTRONOMY, and Dr. Gingrich in turn kindly sent it to us. This note is as follows:

"(Special to the Indianapolis Star.) Linton, Ind., April 1.—Geologists tonight found themselves prohibited from exploring the crater formed by a meteor which fell with a terrific explosion and blinding flash of light late last night on a farm half a mile from the center of population of the United States.

"Late today 'no digging' signs were posted about the crater five feet deep and ten feet wide on the Fred Stretelmeir farm.

"Prof. C. A. Malott, Indiana University geologist, and a staff of assistants inspected the hole and the professor said it was the first time, to his knowledge, that a meteor had landed in this section of the state. It probably was of super-heated stony substance, he said.

"The explosion shook a fifteen-mile radius, breaking windows from homes near the blast scene and spraying hot debris on rooftops of houses in nearby Linton."

This clipping is illustrated with a photograph showing a hole which appears to be at least 10 feet wide and less than 5 feet deep. Eleven men are standing around the edge of the crater and one man sitting in the hole is holding a stick vertically to show the depth.

The most detailed report on the occurrence was received from Professor W. A. Cogshall of the University of Indiana. Mr. Shirl Herr, of Crawfordsville, Indiana, who makes a delicate magnetic balance, reported on a test of the crater with his balance. Other letters furnishing information or enclosing clippings were received.

Let us now consider the possibility of this crater having been produced by a meteor. There was evidently a violent explosion at the time the crater was produced, and if it was produced by a meteor, a considerable amount of material must have been vaporized with explosive suddenness. To strike with a velocity sufficient to produce such an explosion, the meteor must have weighed tons. However, only a small portion could have been vaporized, or a larger hole would have been produced. Evidently, if the hole was produced by a meteor, the main mass is buried beneath the crater. Since meteorites weighing less than a thousand pounds have buried themselves more than 6 feet deep, it appears that the surviving portions of a meteor weighing tons would bury themselves deeply. Bedrock is 8 to 20 feet below the surface, and presumably the larger fragments from such a meteor might drive down to that depth.

Meteors, which have dropped meteorites, burst at a height of some miles. A meteor of fairly tough material and weighing tons might perhaps come to the

surface of the earth without a real bursting, but presumably, fragments would be stripped off in the lower atmosphere where the pressure on the front would be enormous. The fragments stripped off at a low altitude would strike with almost the same velocity as the main mass, and consequently would bury themselves deeply, unless of very small size.

The fall of a meteor through the lower atmosphere is always accompanied by detonations. At the fall of a meteor weighing tons, the actual explosion produced when the meteor strikes the earth would be heard first by persons near the point of fall. The first detonations from the explosion, and other detonations would follow. Unless a meteor falls vertically downwards, detonations are heard much farther in one direction (that from which the meteor came) than in others.

A meteor weighing tons would, for observers within 200 miles, appear almost as bright as the sun. On a clear night the sudden illumination would make the landscape seem much more brightly illuminated than by day. With overcast skies, there should be a brief lighting up of the clouds giving an illumination similar to an overcast day.

Let us now examine the reports of the occurrence to see how well they agree with the meteor theory. Unfortunately, the region where such a bright meteor would have lighted up the landscape was solidly overcast. However, the fact that no light was noticed by persons more than half a mile from the crater is evidence against the meteor theory. For such a large meteor, the light should have been noticed, even with overcast skies, by persons outdoors, or indoors and near a window.

The sound reported appears to have been simply a single violent explosion without the following roar characteristic of a meteor. Further, no evidence has been received that the sounds were heard appreciably farther in one direction than in another. This is, therefore, against the meteor theory.

The crater was surveyed by Dr. T. C. Poulter using the magnetic balance constructed by Mr. Herr. The balance indicated that there was no metallic substance in, or immediately below the crater, excepting a piece of iron wire which had evidently been subjected to the gases of the explosion. No meteoric material, or evidence of a meteorite striking, has been found in the region immediately surrounding the crater. This is strong evidence against the meteoric origin.

The crater is rather wide and shallow. The probing indicated that the sides and bottom are undisturbed soil. It appears that nothing is buried below or in the sides of the crater. If this is correct, it can be considered conclusive proof that the crater was not produced by a meteor. A meteor large enough to strike with an explosive velocity could not have been completely vaporized without producing a larger crater. Presumably, the crater produced by such a meteor would have been deeper, rather than of the wide and shallow type.

Let us now consider the possibility that the crater was produced by dynamite, or other high explosive. The crater is near a big strip mine where dynamite is used regularly. The piece of bright unrusted wire which had evidently been through the explosion suggests that a box or bundle of explosive had been wrapped with wire. The wide and shallow hole suggests a charge on or near the surface. The breaking of windows in the neighborhood suggests a heavy charge of dynamite. Professor Cogshall summed up the evidence and then stated, "That all sounds like dynamite." He added, however, that persons in the community doubted the dynamite explanation because of the violence of the report heard. From observation of blasting in the strip mine, they felt that a charge of dyna-

mite which would make so much noise should have made a larger hole.

From personal observation, however, I know that dynamite fired on the surface makes much more noise than a more deeply placed charge. At some recent blasting operations I observed the firing of carefully placed charges, and also of some sticks of dynamite laid on the surface. A surface charge which would move less than a cubic foot of material made much more noise than a deeply placed charge which would throw a few cubic yards of material high in the air. The blasting in the strip mine is probably all done with carefully placed charges, and the neighbors did not realize how much more noise a surface charge would make.

The opinion these neighbors expressed was also expressed when an explosion produced a slightly larger crater near Malinta, Ohio, on June 10, 1931.* Press reports stated that windows were broken at a distance of a few miles, and that the concussion was violent at a distance of thirty miles. Persons in the vicinity believed that a quantity of explosive which would make that much noise should have made a larger crater. But oil well experts who examined the Ohio crater said that it was produced by nitroglycerine, about 30 quarts.

To summarize—If the first information received is reasonably accurate and complete, the Linton crater was produced by high explosive. Probably a charge of dynamite on, or very near, the surface was fired.

University of Iowa, April 22, 1936.

NOTE ADDED APRIL 30, 1936.

Since writing the above, we have received a clipping from the *Indianapolis Star*, and a letter from Professor W. A. Cogshall reporting on a further examination of the region of the crater and on the results of excavating to a depth of some six feet. A piece of fuse wire about a foot long was found a few feet away from the crater, and in the digging, some additional wire, which had evidently been through the explosion, was found. The ground two feet below the bottom of the crater had evidently not been disturbed in many years. Professor Cogshall is planning to report more fully on the explosion, and the investigation of the crater.

For the information that the sky was heavily overcast over all the region within a few hundred miles of Linton and throughout the night of March 31-April 1, we are indebted to Mr. J. H. Armington, Senior Meteorologist, of the United States Weather Bureau, Indianapolis, Indiana.

*See *Contributions of the University of Iowa Observatory*, No. 2, page 75; POPULAR ASTRONOMY, **39**, 407.

Contributions from the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD, President, *and* H. H. NININGER, Secretary

The Pasamonte, New Mexico, Meteorite

By H. H. NININGER

The arrival of the Pasamonte, New Mexico, meteorite was marked by what was probably the greatest meteoritic display ever recorded in the western hemisphere for a recovered meteorite. This display has previously been described somewhat at length.[1] The purpose of this paper is to describe the distribution of

[1] *P. A.*, **42**, 291-306, 5 figs., 1934.

the meteorite fragments which have been found, to depict their surface features, and to present some opinions with regard to the meteorites and their behavior during flight. The mineralogical characteristics of the material are being studied by Dr. William F. Foshag of the United States National Museum, Washington, D. C.

I shall mention a few important phenomena connected with the fall, which have been verified since the publication of my previous account. Numerous reliable reports give evidence of the fact that the passage of the meteorite was distinctly heard and felt to distances of more than 100 miles both to the north and to the south of its line of flight. The fireball was described as "the largest ever seen" and by some as "terrifying," from distances as great as 300 miles on either side of its course. In the vicinity of its lower passage near the end of the visible flight, many residents insist that they suffered from a throat irritation throughout the entire day following the fall, and that a peculiar sulphurous odor was noticeable for some hours. These impressions seem the more remarkable in view of the fact that dust storms had been raging in the vicinity for weeks and a considerable storm developed on the day of the fall. Those who report the throat irritation insist that it was like nothing experienced previously or since. Mr. Charles M. Brown of Mt. Dora, New Mexico, who obtained the remarkable photograph of the meteor in flight[2] is responsible for the report that all of the people in his neighborhood suffered from this throat irritation, which was said to have been the subject of much discussion during the day of the fall. Since Mr. Brown is a man who at all times seems to be in complete control of his faculties, one feels inclined to give his report serious consideration. The fact that the meteorite ceased to be incandescent at an elevation of 17 miles, accentuates the difficulty of explaining these phenomena; however, we now know that the meteorite was of such a texture that the several witnessed explosions doubtless set free great quantities of extremely fine dust, the particles of which were all sharp-angled like those of volcanic ash. The enormous cloud which hung in the stratosphere for some time after the meteor's passage probably showered particles of this dust in considerable quantity.

My son and I were at Clovis, New Mexico, on the night of March 23, 1933, and, while the meteor was not visible from that point because of cumulus clouds, we heard about it from numerous witnesses in Melrose, 25 miles to the west of Clovis, a few hours later. We set out at once to gather information from witnesses, and by evening had almost completely encircled the end point. The following day was spent in the gathering of further data. Subsequent trips were made, covering numerous points on all sides of the fall, and after some weeks the course was plotted as described in my previous paper.

Under ordinary circumstances, with its path so definitely plotted, we should have been gathering the stones from this shower very promptly; for we now know that a Mexican sheep-herder on the Pasamonte Ranch was panic-stricken by the falling of stones around his camp and that he later carried into headquarters one of the several small black ones which he picked up. A strange misfortune prevented this happy and prompt fruition of our efforts. When, on the day after the fall, we found that we had to return to Denver without completing the survey, I stopped in Raton, New Mexico, and called upon a patron of the Colorado Museum of Natural History, Mr. Fred Howarth. Mr. Howarth was an official of his bank, and traveling over northeastern New Mexico was a part of his regular activity. He agreed to call at the Pasamonte Ranch and several other ranches

[2] *Loc. cit.*, Fig. 1, p. 291.

in that locality in my stead and ascertain whether there had been any odd-looking stones picked up.

The weeks which followed were busy ones for me. My office was flooded with correspondence concerning the fall. Letters arrived from seven States and it was learned that searching parties had actually gone out to explore various parts of Texas, Kansas, Oklahoma, Colorado, Nebraska, and Arizona—all looking for the meteorite which I knew had landed, if at all, in northeastern New Mexico. As time permitted, I strove to perfect my plotting of the meteor's path. One point worried me: the data as to the height of the end point were not in agreement. The majority indicated a height of 12 to 14 miles. However, a certain few reports which seemed to come from the most reliable sources, indicated a height of 17 to 18 miles. Several of these were accompanied by photographs of the persistent cloud. These naturally carried considerable weight.

When a message came announcing the sudden death of Mr. Howarth from a heart attack, I realized that there was yet work to be done in the Pasamonte region. However, I had received a letter from him some days earlier stating that he had inquired throughout Union and Harding Counties without result. All of the literature on meteor paths and meteorite falls made it apparent that the meteorite should be looked for, not under the end point of the visible meteor, but beyond, at a point somewhat short of that at which its projected path encountered the soil. All of my previous experiences had borne out the same idea; consequently I felt that the matter could await my convenience, especially since Pasamonte was several miles back from the point where the meteor vanished. This meteor had traveled at a very low angle, about $8\frac{1}{2}°$ with the horizontal, as attested by observers and as recorded on photographs of its train. Its projected path touched the earth far to the west. A search was attempted in the vicinity of Wagon Mound, 30 miles beyond the vanishing point. To allow for those estimates of greater altitude, a similar effort was made at points still farther on, but all to no avail.

As time went on I checked and rechecked all data, interviewed more witnesses, and kept stimulating the search for stones. I could not give up the search for what was evidently one of the greatest meteoritic falls in history. Except for the disagreement on the matter of height, my data appeared perfectly satisfactory. If only that one point could be cleared up, the search could be restricted to a much smaller area. At last I met Mr. E. H. Wolff of Pueblo, Colorado, who was in a position to settle the question of altitude. From his bedroom window Mr. Wolff had watched the fireball as it "appeared to roll along the comb of the roof" of a neighboring school building. Here it was possible to make an accurate measurement of the angle of elevation from the pillow where rested the observer's head while he watched the moving meteor and saw its extinction. This observation finally settled the matter of height as approximately 17 miles where the meteor had vanished.

It now seemed that an intensified effort of search was justified in the westernmost area previously designated, but the searcher for meteorites has many surprises in store for him. I chanced to be passing through Clayton, New Mexico, on December 23, 1933, and decided to detour via Pasamonte in order to check personally this region in which it seemed there should have fallen some small fragments from a body which had produced such an enormous cloud as this meteor had left in its wake. I regarded this cloud as due to meteoritic dust, and if that idea were correct, then there should have been scattered some sizable chunks of the meteorite which had disintegrated to form the cloud. To my surprise, Mr.

Howarth had not been seen at the Pasamonte Ranch at all; nor had any other investigator been there. Still more surprising was the information that one of the herdsmen had brought to the ranch house just such a fragment as I was seeking. The stone had been very friable and the various men of the force had each "whittled at it with his knife" until it had all been destroyed. Fortunately other herdsmen were known to have picked up some of the same kind of stones, and, although most of these had been mashed to pieces, there were a few still preserved so that we were able to verify the truth of the report. Mr. O. P. Gard, a farmer six miles to the west, had preserved very carefully a stone from the day it had been found. In his wife's diary the date of its finding had been recorded as April 3, 1933, ten days after the fall occurred. This stone was in a perfect state of preservation and is shown in the photograph (Fig. 1).

FIGURE 1 FIGURE 2
Front and rear views of a stone found by Mr. O. P. Gard.
(About natural size.)

The topography of the Pasamonte region may be described as a rolling plain, a grazing land for the most part; however, quite a few fields have been broken up and are used for dry land farming. To the west about eight miles, lie the breaks of Ute Creek whose channel has been deeply cut into the basaltic lava which underlies the entire region. To the east the land becomes more sandy and rather hilly. On the south of Pasamonte, about five miles, the country is broken and rugged. The region is very sparsely settled, rendering a thorough search quite impossible; however, we at once canvassed the entire neighborhood, exhibited specimens, and urged the preservation of any meteorites which might be found. For these we offered attractive prices.

CHARACTERISTICS OF THE PASAMONTE STONES

This campaign soon began to bear fruit, and, in the two years following, resulted in the recovery of some 70 small stones aggregating a weight of about four pounds.[3] The largest stone found weighed less than 300 grams. These meteorites are of the stony (aërolitic) variety classified as *Howardites*. The crust is very

[3] In addition, several stones were gathered by an amateur collector who learned where we had located the fall and who represented himself as being one of my associates. The exact location of some of these falls has not been ascertained.

heavy and dark, and appears vitreous in the best preserved specimens. In most cases, the crust is beset with prominent ridges which appear to have resulted from the congealing of a viscid molten glass. Between the ridges and in some cases traversing them are numerous contraction cracks.

All of the stones were completely incrusted when found, excepting those which appear to have been broken by their impact with the soil. About 50% of them show definite orientation. In those which are oriented, the rear side is largely free from the ridges previously mentioned; it is covered by a rather smooth, tar-like glaze, which is more or less beset with gas bubbles and explosion pits. In some cases this rear crust is marked also by one or more concentrically developed terraces which have been formed by the overflowing of molten glass from the adjacent surfaces. In one instance the junction between the base and the lateral boundary of the stone is denticulated with pointed pyramids of black glass projecting rearward (see Fig. 3).

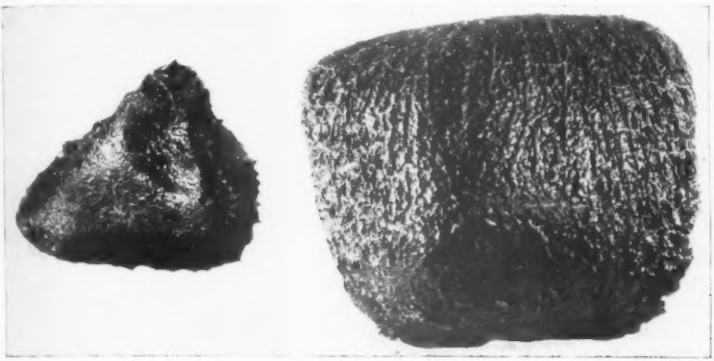


FIGURE 3 FIGURE 4

Figure 3. Oriented stone showing rearward-pointing teeth of glass at junction of sides with base. The front of this stone is relatively free from ridges of glass, in contrast with the stone shown in Figure 4. (Natural size. Nininger Collection.)

Figure 4. Oriented stone strongly marked with ridges of glass. The front of this stone is shown at the top in the picture. (Slightly reduced; side view. Nininger Collection.)

The oriented stones are of two types: in one, the front is comparatively free from ridges, while in the other the ridges are very prominent (see Figs. 1 and 3). With one exception all of the unoriented stones bear prominent ridges. This single exception is incrusted with a glossy layer of black glass and is slightly pitted—the only specimen which shows any pitting. This specimen shows a partially fused interior which is somewhat blackened in places to a depth of several millimeters below the true fusion crust. Its appearance first suggested artificial heating, but we have been unable to learn of any such treatment from the finder.

Distribution of the Stones

Nearly all of the stones found had been left as surface residue; however, in view of the heavy dust storms which have been so frequent in the region, it is possible that some of the stones which have been picked up on the surface were

in reality soil intrusions which had been laid bare by the wind storms. There were cases where two 3-ounce stones were said to have been found half imbedded in the subsoil in fields from which the cultivated layer had been removed by blowing, subsequently to the date of fall. If these reports are true, these stones had buried themselves to a depth of about four inches in dry tilled soil, because we know that the blowing occurred after the meteorites fell. There is some uncertainty about these cases, however.

This fall established a new record as to the distance of separation between members of a single fall and also by the fact that all finds have been made back of the end point of the visible meteor. The nearest approach to the end point of the visible meteor was about 10 miles, and the various other fragments were scattered back along the trail from this point to a distance of 28 miles. In this statement we are using as the location for the end point that which can be relied upon as conservative. Some very good evidence has been submitted to indicate that the meteor continued farther before it disappeared. It is not improbable that it proceeded actually as far as 20 miles in a diminished form, beyond the point which has been designated in my survey as the end point; but we may be sure that the point designated in the survey is about correct for that place where the greater part of the light vanished. By the majority of the observers, no light was seen beyond this point. However, the meteor's brilliance was such as temporarily to produce a blinding effect, and it is probable that those persons who insist that the light carried farther were those whose eyes recovered from the effect of the dazzling brilliance more promptly than did the eyes of the other observers. In any case, the entire distribution of stones, as far as has been discovered, fell far short of the end point of the meteor. The only comparable case that I have been able to find on record is that of the Rochester, Indiana, stone. This stone is credited to the great procession of December 21, 1876, which proceeded, according to Kirkwood, about 200 miles after it passed Rochester, where the stone fell.

After I had spent weeks of time and several hundred dollars in an effort to complete a reasonably accurate survey of this important fall, it was gratifying to learn that the distribution of stones conformed to the line of flight which I had designated. The line which had been drawn on my map months before the first stone was reported, still remains where originally placed at its west end. It lies about four miles to the south of the meteorite-sprinkled area and almost parallel to it. This northerly displacement of the meteorites is what one would expect in view of the fact that a brisk wind blew from the south on the morning of March 24, 1933. Stones averaging one ounce each in weight would have drifted considerably to the north of their target in falling twenty miles. The explosion or explosions which set these stones free must have occurred above this height. At its eastern extremity, the meteorite field lies about five miles north of the designated line of flight. This extremity, being 25 miles farther back along the course of the meteor, where the elevation of the fireball was about one-seventh greater than at the end point, would allow for a correspondingly greater displacement of the falling fragments by air currents.

The large persistent cloud which the March 24, 1933, meteorite left in the stratosphere is regarded by the writer as the most significant aspect of this remarkable fall. Indeed it may be expected that when the scientific world becomes sufficiently aware of their magnitude and the nature of their production, meteoritic clouds will be regarded as among the most important of terrestrial phenomena. A few writers have emphasized to some extent the size of these clouds, but apparently in the minds of most scientists they are very insignificant. I have called at-

tention to the size of this cloud in my previous paper;[4] but at that time there was some uncertainty in regard to its true nature, because the meteorite had not then been found. Now that the meteorite has been examined, it seems quite evident that the cloud was just what it appeared to be, namely, finely comminuted meteorite which escaped volatilization and liquefaction as it was discharged in flight. The meteorite consists of a tufaceous material much of which is so finely divided that, when a piece of the stone is broken or rubbed, it emits a cloud of dust so fine that it rises like smoke from a cigarette. This material is now believed to have been mainly responsible for the unusually large cloud which followed the meteor; in ordinary falls the resulting cloud is often only a few cubic miles in extent. Whether one or a thousand cubic miles in volume, a cloud in the stratosphere left by a meteor is an important phenomenon. Every available means should be brought to bear upon the significant questions which arise as to the nature and mass of these gigantic apparitions whose dimensions surpass those of nearly all other terrestrial objects which are viewed by man.

Recent discoveries by aërodynamical engineers throw much light on this aspect of the March 24, 1933, meteor and meteorite. These workers have found that atmospheric resistance, where high velocities are involved, is far greater than had been formerly supposed. At the speed of sound or thereabouts, instead of the atmospheric resistance varying as the square of the projectile's velocity, as had been considered the rule for ordinary vehicular rates of travel, they find that the resistance varies as the *sixth* power of the velocity! This astounding increase in the ratio between velocity and resistance can only weakly suggest what is probably the ratio at velocities such as characterize the flight of meteorites. The average meteorite enters the atmosphere traveling about 130 times as fast as sound. This number raised to the sixth power gives us the unthinkable figure of 4,826,809,000,000! The highest power steel-jacketed bullet leaves the muzzle of a gun with a speed about three times that of sound. The air resistance at this speed is sufficient to melt lead or to produce a temperature of perhaps 350° to 500° C. According to the preceding formula, the resistance offered to an invading meteorite should be about 4,000,000,000 times as great as that encountered by a bullet in a medium of the same density. The outermost zone of the atmosphere is of course very tenuous, but even so, it is evident that the conflict between meteorites and our atmosphere must be extremely violent. The March 24, 1933, meteorite encountered the earth in almost a direct head-on collision, with a relative velocity of about 40 miles per second. The resistance which it experienced was no doubt sufficient to keep its surface layers in a state of constant violent volatilization. In other words, there was a protracted explosion in progress all over the forward and lateral exposures of the meteorite. This process in a fair way represented the rocket idea except that in this instance the rocket was traveling at high speed and was being checked by the rocket-propelling principle acting in reverse. As the velocity was reduced, the volatilization gave place to liquefaction which was responsible for the glassy incrustation with which each fragment finished its course.

Throughout the burning flight there was much crumbling or crushing of the meteorite, and some of the débris thus produced escaped both fusion and volatilization and was driven outward to form the cloud of gray material which persisted in the stratosphere. This cloud no doubt rained minute particles over hundreds of square miles during the hours which succeeded the meteor's passage. Unfortunately, our survey was not finished promptly enough to verify this assump-

[4] *Loc. cit.*, pp. 295-8.

tion. Shortly after the meteor's passage, a strong wind from the south filled the air with dust and sand which would have caused any rain of meteoritic particles to be overlooked by the untrained residents.

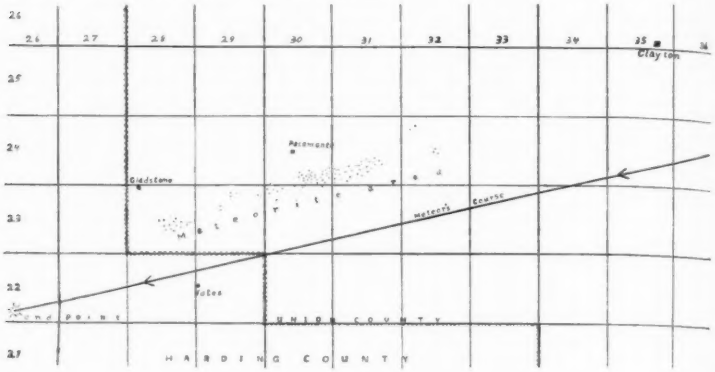


FIGURE 5

Township map of the southwestern part of Union County, New Mexico, showing the path of the March 24, 1933, meteor and (roughly) the distribution of the meteorites subsequently recovered near Pasamonte, *i.e.* the meteorite-sprinkled area. (Survey by the Nininger Laboratory.)

The accompanying map shows the distribution of the stones which were found. In general the larger stones were toward the western end of the area in Twp. 23 N, R 28 E.

The Fourth Annual Meeting

As announced in the May issue (p. 283), the Fourth Annual Meeting of the Society will be held at the University of California at Los Angeles on June 23 and 24, 1936. At the morning session on June 23, Dr. Arthur S. King, Superintendent of the Physical Laboratory of the Mount Wilson Observatory, Pasadena, by invitation will read a paper (illustrated) on "The Spectra of Meteorites," and at the afternoon session on the same day, Dr. Mars F. Baumgardt of Los Angeles, also by invitation, will deliver a semi-popular illustrated lecture on "The Meteorite Crater of Arizona." All the scientific sessions of the meeting will be open to the public.

Secretary's Office: Nininger Laboratory, 1955 Fairfax Street, Denver Colorado.
Editorial Office: Department of Astronomy, University of California at Los Angeles.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Observers and Observations: Two new observers appear in the list of contributors for April, Mr. Hideo Inouye, of Nagoya, Japan, and Mr. A. Thomas Murphy, of San Francisco, California. In spite of the inclement weather reported

from all sections during the quarter just closed (February-April), approximately 8600 observations were contributed. The contributors and the approximate number of observations to be published are listed below.

Name	Initial	Location	Observations
Adamopoulos	Ap	Athens, Greece	3
Ahnert	Ah	Wittgensdorf, Germany	218
Albrecht	Ab	Milwaukee, Wisconsin	3
Andrews	Aw	Rutherford, New Jersey	1
Armfield	A	Milwaukee, Wisconsin	90
Baker	Bk	Cambridge, Massachusetts	1
Baldwin	Bl	Melbourne, Australia	442
Bappu	Bp	Begumpet, India	44
Beck	Bv	Denver, Colorado	3
Belsham	Bm	Miami, Florida	336
Benedict	Bf	Alliance, Ohio	1
Blunck	Bu	Minneapolis, Minnesota	26
Bouton	B	St. Petersburg, Florida	163
Bradbury	Bd	Alliance, Ohio	1
Brocchi	Br	Seattle, Washington	106
Brockmeyer	Bx	Fredonia, Kentucky	8
Brown, S. C.	Bs	Hanover, New Hampshire	6
Buckstaff	Bc	Oshkosh, Wisconsin	75
Callum	Cl	Chicago, Illinois	67
Cameron	Ca	Inwood, L. I., New York	40
Chandra	Ch	Bagchar, India	97
Christman	Cm	Farmingdale, L. I., New York	87
Cilley	Cy	Romney, West Virginia	90
Crout	Ct	Baltimore, Maryland	27
Dafter	Df	Brisbane, Australia	76
Dahm	Dm	Oshkosh, Wisconsin	59
Dalton	Dt	Alhambra, California	31
Diedrich	Dh	Milwaukee, Wisconsin	16
Doolittle	D	South Norwalk, Connecticut	169
Ellis	Es	Portland, Oregon	134
Ensor	En	Pretoria, South Africa	242
Erro	Er	Mixcoac, Mexico	163
Fairbanks	Fb	Waterloo, Iowa	6
Farnsworth, Miss	Fa	South Hadley, Massachusetts	22
Focas	Fc	Athens, Greece	247
Franklin	Fl	Rocky Point, L. I., New York	21
Friton	Fn	St. Louis, Missouri	14
Gregory	Gy	Scipio Center, New York	70
Haas, W.	Ha	Alliance, Ohio	7
Halbach	Hk	Milwaukee, Wisconsin	50
Hamilton	Hm	Norwalk, Connecticut	279
Hartmann	H	Springfield, L. I., New York	642
Heines	Hn	Paterson, New Jersey	71
Herbig	Hg	Los Angeles, California	223
Hiett	He	Hedgesville, West Virginia	57
Hildom, A.	Hi	Bell, California	67
Holt	Ho	Scarboro Beach, Maine	42
Houghton	Ht	Cape Town, South Africa	454
Houston	Hu	Milwaukee, Wisconsin	27
Howarth	Hh	Newcastle, Australia	22
Howes	Hw	Belen, New Mexico	15
Inouye	In	Nagoya, Japan	6
Jones	J	Goffstown, New Hampshire	860
Kanda	K	Tokyo, Japan	29
King	Kg	Amityville, L. I., New York	15
Kirkpatrick	Kp	New York City, N. Y.	18
Kitchens	Kc	Norman, Oklahoma	14
Knott	Kt	Milwaukee, Wisconsin	2

Name	Initial	Location	Observations
de Kock	dK	Izulwene, South Africa	327
Kotsakis	Ks	Athens, Greece	79
Kozawa	Kw	Nagoya, Japan	42
Lacchini	L	Trieste, Italy	16
La Fon	LF	Norman, Oklahoma	38
Loepfe	Lf	Milwaukee, Wisconsin	4
Loreta	Lt	Bologna, Italy	97
McLeod	Mc	Christine, North Dakota	60
McNeill	Ml	Evanston, Illinois	20
Millard	Md	Portland, Oregon	146
Moore	Mo	Louisville, Kentucky	12
Murphy	Mu	San Francisco, California	5
Okano	Ok	Aichi-Ken, Japan	10
Peck	Pe	Milwaukee, Wisconsin	76
Peltier	Pt	Delphos, Ohio	423
Perkinson	Pk	Fresno, California	12
Purdy	Pu	Lodi, California	13
Recht	Rh	Denver, Colorado	2
Recinsky	Rc	Rowena, Texas	38
Rosebrugh	Rb	Poughkeepsie, New York	189
Roth	Ro	Alliance, Ohio	1
de Roy	Ry	Antwerp, Belgium	119
Salanave	Sv	San Francisco, California	56
Schattle	Sc	Syracuse, New York	29
Seely	Se	New York City, N. Y.	13
Shinkfield	Sh	Adelaide, Australia	92
Shultz	Sz	Montclair, New Jersey	27
Sill	Si	Mamaroneck, New York	40
Simpson	Sp	Webster Groves, Missouri	13
Smith, F. P.	Sm	Atlanta, Georgia	28
Smith, F. W.	S	Glenolden, Pennsylvania	3
Smith, L.	Sl	Brooklyn, New York	9
Smith, L. L.	Sx	Rainton, Canada	2
Starnes	St	Monroe, North Carolina	16
Thomas, Mrs.	To	Cambridge, Massachusetts	5
Thorndike	Tr	Wellesley, Massachusetts	16
Thorne	Th	Patchogue, L. I., New York	3
Treadwell	Td	Arlington, New Jersey	12
Vessey	Vs	Rowayton, Connecticut	7
Wade	Wd	Los Angeles, California	4
Walton	Wu	Denver, Colorado	81
Watson	Wa	Baltimore, Maryland	84
Webb	W	Jamaica, L. I., New York	142
Weiss	We	Magill, Australia	10
Woods	Wo	Baltimore, Maryland	46
Totals	103		8572

Volume 104, No. 1, of the *Harvard Annals*, containing the first quarterly report (November-January) has been distributed to regular observers.

V Hydrae Type Variables: Attention was called in 1926 to the long-term period found to exist for V Hydrae, 1046*p*, besides the more or less irregular period of 527 days which seemed to prevail. This long-term period appeared to cover an interval of seventeen years and so far as then known, no other variable of spectral class N showed such a phenomenon. The star had a range of approximately two magnitudes between consecutive maxima and minima in the 527 day interval, with a maximal range over the seventeen years of approximately six magnitudes. V Hydrae is due to reach a deep minimum, around the twelfth magnitude, in the year 1942.

No other star similar to V Hydrae was known until 1933, when Dr. C. Payne

Gaposchkin announced that W Orionis, 050001, another red variable of spectral class N, was found to have a short-term period of 200 days and a long-term period of 2000 days. W Orionis is brighter visually than photographically and the visual range is considerably smaller than the photographic range—a characteristic found also in other long-period variables of spectral class N. Are there other class N stars which also have both relatively short and long-term periods? If there are two, why not more? All such stars suspected of having similar double periods are being examined on plates of the Harvard collection and the question of the disparity in range of W Orionis as observed visually and photographically will soon be put to a careful test by photo-electric methods by one of the A.A.V.S.O. observers.

Irregular Variables in Corona Australis: Attempts by visual observers to find periodically repeated light curves for the variables R, S, and T in the constellation Corona Australis have so far proved unavailing. All these stars, on the A.A.V.S.O. observing list for a number of years, have been assiduously followed, but nothing satisfactory has been found. A recent photographic study of this same region of the sky, in which these three variables together with three others are found, has been made by Drs. C. Payne Gaposchkin and S. Gaposchkin and shows that all are varying in the same irregular manner. It is a satisfaction to learn that the photographic light variations agree perfectly with the visual variations, at least with respect to times of observed fluctuations. It is to be noted that there are dark clouds of obscuring nebulosity in the surrounding region; very probably these stars are actually situated within the nebula and R Coronae Australis, at least, may be lighting up some of the nebula by reflection. It is probable that we may thus be able to determine not only the distance of the nebula but the intrinsic brightness of the stars within its confines. Most of the stars are comparable in brightness, temperature, and size, to the sun. They resemble in many ways the numerous variables which are found enmeshed in the Great Orion Nebula. Most long-period variables, Cepheids, and semi-regular variables are definitely giant stars, of much greater luminosity than the sun and accordingly, to find a group of dwarfish variables in Corona Australis is a matter of genuine interest.

Super-Novae: When a nova is found which exceeds by a thousand times the brilliance of an ordinary nova, we call it a super-nova. Few such stars have been found in our own galactic system, the only one which can claim that distinction having been Tycho Brahe's Nova of 1572, which surpassed Venus in brilliance. Ordinary novae, of which Nova Herculis may be called a well-known and most recent example, are known to attain a maximum luminosity ten thousand times that of our sun.

More than a hundred novae have been found in other galaxies the first having been discovered in the Great Andromeda Nebula by Gully in 1885. This proved to be a real super-nova with an absolute magnitude of —15.4, as compared with an average value of —6.0 for most other novae. Dr. Stratton in his latest work on novae cites 85 galactic novae up to and including Nova Herculis. He lists 116 found in the nearby external galaxy of Andromeda, discovered mainly in studies of the Mount Wilson plates. It is vastly easier to find such novae in external galaxies than within our own galaxy since hundreds of plates are required to cover the whole Milky Way. More than a dozen super-novae have been detected in as many stellar systems during the past two decades.

According to the work of Dr. C. Payne Gaposchkin and others, we understand the spectra of ordinary novae, at least in their main features; they show

evidence of a terrific stellar explosion, the surface of these stars flying off with a velocity of from 500 to 1000 kilometers a second. The spectra of super-novae (which have extremely faint apparent magnitudes) have, until quite recently, remained a real mystery. There now appears to be good evidence that these highly luminous stars differ from lesser novae only in the violence of the explosion, which blows off their surfaces at the rate of 6000 kilometers a second. The spectra of such super-novae have been well enough photographed to be studied in some detail. The spectrum of the super-nova Z Centauri, 1895, shows it to consist of the same spectral lines as are found in ordinary novae, but considerably blurred because of the tremendous speed at which it was expanding at the time. Two spectra of super-novae have appeared in other systems, one in 1926 in NGC 4303 and the other in 1936 in NGC 4273, both in the constellation Virgo. These spectra have been published recently at the Mount Wilson Observatory and they lead to the same conclusion as that drawn from a study of Z Centauri. In other words, super-novae represent a phenomenon similar to that of ordinary novae but on a vastly more gigantic scale.

From the rate at which novae appear in the Great Andromeda Nebula, we might conclude that many more novae appear and disappear in our own galaxy without detection, thus confirming Bailey's inference that novae are frequent occurrences within our own stellar system. Perhaps there are twenty-five novae a year which reach at least the ninth magnitude.

SS Cygni Type Variables: Maximum No. 186 of SS Aurigae proved to be of the slowly rising type, rarely found to occur for this peculiar variable. Five days were occupied in increasing from magnitude 14.7 to 10.9 though usually the increase occupies not more than thirty-six hours. This event associates SS Aurigae more closely with SS Cygni than with U Geminorum, for which case so far as has been observed, the rise to maximum is invariably rapid.

The SS Cygni type variable X Leonis, 094512, was observed at magnitude 12.9 by three observers on March 19: evidently the maximum was of very short duration, because on March 17 and 21 the variable was recorded as fainter than magnitude 13.5.

Color Variations of Beta Herculis: The Sixth Annual Report of the Star Colour Section of the New Zealand Astronomical Society, by A. G. C. Crust, contains an interesting item regarding color variations of the eclipsing type in Beta Herculis. He reports a period of about 12.6 days and a duration of eclipse of about 2.2 days for the principal minimum, and 1.1 days for the secondary minimum. Dr. Crust assumes that there is a third body in the system of Beta Herculis, and since the color variation period of 12.6 days is not indicated by radial velocity observations, it is believed that the small blue star, whose spectrum is visible, is accompanied by a giant star at a distance appropriate to the period and combined mass, while the principal body of the system shows its period to be 411 days because of its revolution around a common center of gravity with the eclipsing pair.

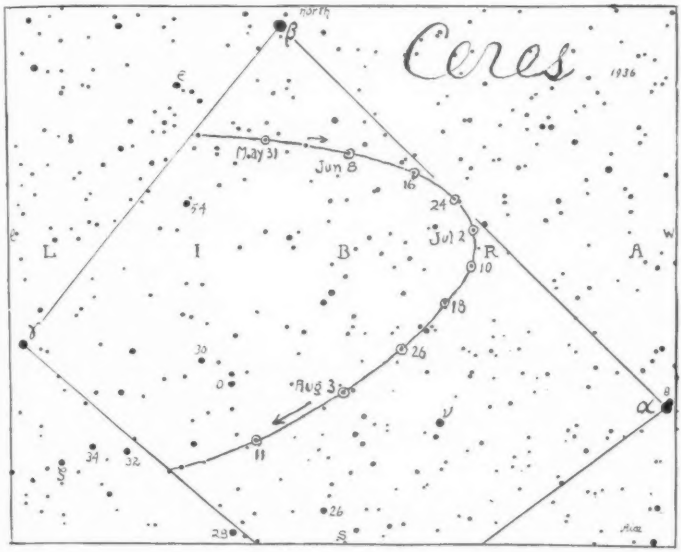
The observational data lead to the conclusion that the diameter of the third star in the system is 12.2 solar diameters, the mean distance between it and the blue component being 0.14 astronomical units, while the combined mass of the system is 2.3 times that of the sun.

May 18, 1936.

Asteroid Notes

By HUGH S. RICE

For early summer observation of minor planets with small telescopes, it is suggested that Ceres and Pallas are the best ones available. The Pallas chart in our May issue will be found of use until July 15. Juno and Vesta are too near the sun to be observed this season. We have prepared a chart of Ceres, which is number 1 of these objects.



Ceres was discovered 135 years ago at Palermo, and it encouraged the hunt for other minor planets, but no others have been found, that are larger than Ceres, altho Vesta is brighter. The diagram shows the apparent path among the stars in Libra, and the exact positions at 6:00 P.M. (C.S.T.) on the dates marked. Libra is on the meridian at 9:00 P.M. toward the end of June; we have outlined the diamond shape of this star group, for identification; first pick up the naked-eye star β Librae. A yellow-and-purple double star, ι Librae, is just below the bottom of the chart. The faint companion needs a 3- or 4-inch glass.

The magnitude of Ceres declines from $7^{M}.4$ to $8^{M}.1$ during June and July. It will be seen to turn from its retrograde motion early in July, and resume its eastward course. Numerous stars are lying on Ceres' track, so that several interesting conjunctions will take place. The moon will be in conjunction with Ceres on July 1, but will be about 8° south of the planet.

As usual, hundreds of other asteroids are observable, but they are mostly faint, and below magnitude 10. However, there is one fairly bright one, 387 Aquitania, of $8^{M}.2$, going from southwestern Aquarius to southwestern Capricornus in July and August. In the former position it is near Messier 72. It was

discovered March 5, 1894, by Courty at Bordeaux, and was then of $10^{M}.0$. The ephemeris of Aquitania which follows was computed by the Astronomisches Rechen-Institut.

ASTEROID EPHEMERIS. EQUINOX OF 1925. FOR 0^{h} G.C.T.

387 AQUITANIA

	α	δ
1936	h m	° ′
July 11	20 46.2	−12 57
19	20 41.4	−14 53
27	20 35.7	−16 58
Aug. 4	20 29.6	−19 4
12	20 24.0	−21 3
20	20 19.7	−22 51

Hayden Planetarium, American Museum of Natural History,
New York City, May 20, 1936.

General Notes

The Rittenhouse Astronomical Society of Philadelphia held its monthly meeting on Friday evening, May 8, 1936, in the Hall of The Franklin Institute. A lecture on the topic "Astrophysics in Trans-Oceanic Telephony," illustrated with slides and motion pictures, was given by Dr. A. M. Skellett, Research Physicist of the Bell Telephone Laboratories.

The Syracuse Astronomical Society held its first meeting of the season at Lyman Hall, Syracuse University, on Tuesday evening, April 21. The title of the lecture at this meeting was "A Tour of the Universe," which was given by Dr. Ernest Cherrington, president of the Society, and illustrated by some very splendid slides. Dr. C. J. Kullmer, Vice-President of the Society, gave a brief talk on the history of the Society, and introduced the speaker of the evening. The attendance was sixty-five. New members were also received at this time. A second meeting was held on May 12, at which time Dr. C. J. Kullmer spoke on the subject "Galileo and Copernicus."

A New Observatory in Argentina

Word has been received that on December 12, 1935, a Cosmic Physical Observatory was inaugurated in the San Miguel district, situated on the Pacific Line, some 30 kilometers from the center of Buenos Aires. The President of the Republic together with the Ministers of Public Instruction and Agriculture were present on that occasion.

This new institution, although belonging to the Society of Jesus and directed by it, has been founded through the initiative of the National Council of Observatories and is regarded as a public observatory. It is an improved reproduction of the Ebro Observatory of Tortosa, Spain. When completely equipped, it will study the sun and the universe in general, and also various terrestrial phenomena, especially electrical and magnetic. There will be an electro-meteorological section, which, in addition to the current phenomena of classical meteorology, will register the atmospheric electricity, the ionization of the air and the earth currents.

The newly established Observatory does not confine itself to scientific re-

search, but also to the dissemination of its knowledge. It has already published several pamphlets of a popular character and has others in prospect.

Professor Ignacio Puig, S. J., is the director of the new observatory, known as the San Miguel Observatory.

Coöperation with Science Service

Authors of manuscripts submitted to this journal who wish to publish related supplementary material or longer versions than those accepted for publication may submit manuscripts embodying such material for approval. After this approval these manuscripts will be forwarded to *Science Service* for publication as *Science Service* Documents available in the form of microfilms or photoprints. Such manuscripts should be typewritten in an acceptable standard form (black fresh ribbon on 8½x11-inch bond paper, single spaced, preferably pica type) and should have any photographs or figures separately mounted on sheets of the same size.

In these cases a footnote will be appended to the article as published stating that the more extended version or, as the case may be, the supplementary material is obtainable through *Science Service*. The cost, payable in advance by check or money order to *Science Service*, 2101 Constitution Ave., Washington, D. C., will be stated in the footnote. *Science Service* Documents in microfilm form (images 1 inch high on standard 35 mm motion picture film) will cost approximately 1 cent a page; in photoprint form (6x8 inches in size, readable with the unaided eye) approximately 5 cents a page.

Science Service also operates as a service to scientific research workers the Bibliofilm Service which copies to order literature in the Library of the U. S. Department of Agriculture. Full information and order blanks for Bibliofilm Service and information about mechanisms for reading microfilms will be furnished free on request to *Science Service*.

Prize Offered for Manuscript in Science

A cash award of $1,000.00 is offered by The Williams & Wilkins Company for the best manuscript on a science subject, presented before July 1, 1937. Literary prizes are relatively common, but it is not so usual for a publisher to be bidding for science material in this manner. The publishers put no limitations on the subject-matter or manner of handling, and none on eligibility for the award. The manuscript must be in English and "of a sort calculated to appeal to the taste of the public at large." The desired length is given as 100,000 words. While any manuscript on a science subject will be considered, it is expected that the author will prove to be a man or woman engaged in a scientific pursuit and who is possessed of the requisite literary skill to interpret science for that portion of the public which reads books.

To assure authenticity, the publishers have enlisted the services of some 25 or 30 "advisers," these being men of science of wide reputation and assured competence. One or more of the advisers will pass upon each manuscript from the viewpoint of soundness and accuracy.

The award will lie in the joint discretion of four judges selected with a view to their especial qualification in choosing the sort of book that will appeal. These are: Dr. Joseph Wheeler, Librarian of the Pratt Library in Baltimore, and chairman of the Book List Committee of the American Association for the Advancement of Science; Harry Hansen, reviewer and critic for the New York World Telegram and Harpers Magazine; Dr. Lyman Bryson, Professor of Edu-

cation of Teachers College Columbia, and Director of the "Readability Laboratory"; and David Dietz, science editor of the Scripps-Howard newspapers.

Further details concerning the award may be had by addressing the publishers at Mt. Royal and Guilford Avenues, Baltimore, Maryland.

Book Reviews

Handbuch der Astrophysik, Band VII, Ergänzungsband. (Julius Springer, Berlin, 1936. Price 126 marks. 718 pages.)

The several volumes of this great work appeared at various times from 1928 to 1933. In view of this the material was not uniformly up to date. This new volume covers the entire field of astrophysics and brings the various parts in harmony as to date—all important work published to the end of 1934 having been taken into consideration. For the most part the same authors who wrote the original parts also assisted in their respective subjects in the new volume.

In addition to the great value of uniform dating for all portions of the combined work there is included at the end of this volume a very complete subject index of 34 pages which covers the entire work of seven volumes. All those who possess the first six volumes will want this one to complete the set. It is to be hoped that the publishers will issue, from time to time, similar supplementary volumes as they will prove to be of great value to all who are interested in keeping abreast of the times in the wide field of astrophysics. E.A.F.

Stars and Telescopes, by James Stokley. (Harper and Brothers, New York City. $3.00.)

Recent years have seen not only a tremendous increase in general interest in astronomy but also the appearance of many excellent books dealing with various phases of the subject. In "Stars and Telescopes" Mr. Stokley, who for some years has been in charge of the Fels Planetarium of the Franklin Institute, skilfully uses his wide experience and handles the subject in a popular yet fully scientific manner. In a brief review only a few subjects can be mentioned, but the chapters dealing with the invention and perfecting of the various forms of telescopes were read with special pleasure, as one finds information collected there which is most difficult to obtain elsewhere without exhaustive study. Also the histories of certain observatories and the instruments used therein are of much interest. One is struck with the inclusion of information about recent advances in the technique of making large mirrors, descriptions of the very latest forms of astronomical clocks, and remarks on the possibilities of television applied to astronomy, and on the use of the photo-electric cell. In the discussion of photometry, however, the reviewer does not agree with the expressed opinion that the wedge photometer is "obsolescent." The moon is especially well treated, and the recent work indicating that its surface is covered with pumice, with the inferences as to the origin of lunar craters, is clearly explained. Incidentally the use of capitals when dealing astronomically with the words Sun, Moon, and Earth, a practice which the reviewer would like to see universally adopted, is to be highly commended.

Mr. Stokley avoids the error made by so many writers of scientific books intended for the general public: he gives controversial theories fairly, without him-

self attempting to pass upon their validity. This is noted with special gratification in the closing chapters, which deal with evolution and the spiral nebulae. There is an innovation in having all 49 of the excellent plates in one group, rather than scattered. The juxtaposition of spectra and direct photographs of the same objects was a particularly happy thought. An occasional error has been noted. Perhaps the statements on page 155 that the Moon rotates on its axis in one synodic month and on page 199 that the image of Mars is larger photographed in infra-red light than in ultra-violet are the most important. The statement on page 223 that the Leonids are doubtless the remains of Tempel's Comet of 1866 is open to question, though their connection is certain. Both comet and meteors are probably remains of a larger comet almost wholly disintegrated by 1866. On the whole, however, the book seems remarkably free from misstatements, a few of which slip into all first editions.

In conclusion, the book is clearly written, with careful attention to scientific accuracy, and is both interesting and well suited for its purpose. It is heartily recommended to the intelligent reader who desires a general outline of modern astronomy brought up to date with the latest information.

CHARLES P. OLIVIER.

Flower Observatory, Upper Darby, Pennsylvania, 1936 May 4.

Highlights of Astronomy, by Walter Bartky. (The University of Chicago Press. $2.50.)

If one is somewhat taken aback upon first looking into this volume, his mental equilibrium is restored upon the realization that the text was prepared with a definite purpose in mind. It is one of the eight "New Plan" texts recently issued for use in the new undergraduate curriculum at the University of Chicago. This particular text is being used for the astronomical portion of the Introductory General Course in the Physical Sciences. Since the "new plan" is different from the old plan, it is reasonable that the texts used should also be different from the old ones.

With these facts in mind one looks a second time at those illustrations which at first created an impulse to smile. Moreover, as he reads more closely the text accompanying and bearing upon them he sees that there is a lesson in each one and that they, in a very unusual degree, impress upon the mind the astronomical facts they are intended to convey. In fact, no matter at what page one may begin his reading, he finds himself reading on and on because of the captivating style and the conviction of authenticity of the author. The arrangement of topics differs somewhat from that of the average text in astronomy. The relative emphasis also is not that generally given. For instance, the chapter on Celestial Mechanics is expanded somewhat which is easily explained as due to the particular interest of the author.

On the next to the final page of the book the author presents a new illustration to enable the reader to visualize the universe as it is regarded today. Because of its freshness and vividness we quote it here as follows:

"For every point of light visible in the sky there are millions of stars in our galaxy that we cannot see without optical aid. Our galactic aggregate is believed to exceed the total population of the earth. To obtain some idea of the immensity of the quantities involved, imagine cutting out each and every letter on the even-numbered pages of this book and then dividing every one of these letters into, say, two thousand fragments. Roll the particles of this paper-dust into balls ranging

in size from a thirty-thousandth to a thousandth of an inch, representing the dwarf stars and stars comparable with our own sun in size. What is left of the book could be used for spheres a hundredth to a tenth of an inch—the giants and supergiants. Now scatter those minute pellets so that they are about a mile apart and are occupying a disk ten times the radius of the earth. The result would be a model of the galaxy.

"If the reader would like to complete his picture of the now known universe, he must augment this hypothetical operation by pulverizing five million books and distributing the resultant disks (one disk per book) throughout a sphere of radius one astronomical unit. What lies beyond no man knows. Whether the stars continue without end or whether the universe has a definite boundary remains, and perhaps will always remain, a topic for speculative argument."

An ingenious invention termed the Stellarscope is intended to accompany this text. It consits of a small piece of apparatus, easily held in one hand, so constructed as to enable the student to view an illuminated photographic film upon which the naked-eye stars of the several constellations are depicted at the same time as he is looking at the sky, thus making the identification of familiar stars easy. This is purchasable for two dollars.

In conclusion the reviewer wishes to state that, although the text was prepared with a particular situation in mind, in his opinion it is admirably adapted for use in any beginning course in astronomy, also that the casual reader may secure accurate and recent information from it and derive much pleasure in doing so.

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